Traffic and Safety Sciences

Interdisciplinary Wisdom of IATSS

International Association of Traffic and Safety Sciences

TRAFFIC AND
SAFETY SCIENCES

Traffic and Safety Sciences

Interdisciplinary Wisdom of IATSS

International Association of Traffic and Safety Sciences

Traffic and Safety Sciences: Interdisciplinary Wisdom of IATSS

First edition (Commemorative publication to mark the 40th anniversary
of the founding of IATSS), March 31, 2015

Compiled by the International Association of Traffic and Safety Sciences
3F, Honda Yaesu Building,
6-20, 2-chome, Yaesu, Chuo-ku, Tokyo, 104-0028, Japan
TEL: +81-3-3273-7884
FAX: +81-3-3272-7054
http://www.iatss.or.jp/

Production Assistance: The Japan Times, Ltd.
ISBN 978-4-9900252-3-6

INTRODUCTION

To improve safety and sustainability in today's mobility society, it is necessary to bring together all the relevant knowledge from across a broad range of disciplines, including the natural, social, and cultural sciences. Due to the continued but uneven worldwide growth of motorized transportation, disparities in daily mobility and access to life opportunities are widening between developed and developing countries and between metropolitan and local areas. This suggests that it is necessary to establish approaches that take into account the diversity of mobility society. Therefore, we must establish a study of traffic and safety sciences that is based on scientific evidence, rooted in area-specific situations, and searches for interdisciplinary and practical knowledge. This book was developed as a preliminary textbook to address such needs in advance.

The International Association of Traffic Safety Sciences (IATSS) celebrated its 40th anniversary in 2014, and publication of this book is a part of a commemorative project. IATSS, which is characterized by its international and interdisciplinary nature, issued this book for domestic and overseas use as a compilation of the knowledge generated through its projects, especially those conducted over the past 10 years. The book has been published simultaneously in Japanese and English to promote education and research in the field of traffic and safety sciences, and there is hope that the English version in particular will be useful in developing countries in Asia.

This book consists of two sections: Theory and Practice. The writing of the Theory section was led by the editorial boards of the official IATSS journals, *IATSS Review* and *IATSS Research*, the latter of which publishes English-language articles. Authors were selected from the fields of traffic engineering, urban engineering, electronics, information and communication engineering, mechanical engineering, environmental studies, psychology, medicine, law, public administration, economics, and sustainability science, and the essence of the knowledge in each of their individual fields is connected in an interdisciplinary manner. To develop the Practice section, 46 proposed research projects conducted at IATSS during the last 10 years were reviewed and 20 were ultimately selected for inclusion. Each project accurately captured the current situations of domestic and overseas mobility societies and the practical wisdom needed to improve each situation was outlined.

The content of this book is linked to the main theme of our 40th Anniversary Symposium, 2024 IATSS Designs for Mobility Society: Designing Ideal Mobility Society for 10 Years Down the Road. Keywords such as "diversity" and "transmodal" describing the mobility society after 10 years attracted attention at the symposium. "Design" abilities that combine vehicle technology, infrastructure, space, institutions, and culture as well as transmodal thinking are required to make the transportation system safer and more comfortable for diverse users, to meet various social needs, and to transform travel demand—currently considered to be mostly a derived demand—into something that gives the joy and freedom of mobility when using the system. We would be more than happy if this book, brought to publication after much discussion, can serve as a guidepost to show the direction and vision of the next-generation mobility society.

Special features and application of this book

This book, *Traffic and Safety Sciences*, which attempts to broadly address various issues surrounding the mobility society, is a compilation of the wisdom of experts in various academic fields about technologies and social systems that ensure traffic safety.

The Theory section is composed of 11 chapters, and in each, experts explain keywords and phrases that are essential for study of the next-generation mobility society. Therefore, it is not necessary to begin from the first chapter; the contents of each chapter are accessible even if read out of order. The flow of this book is as follows.

In Chapters 1 and 2, experts in urban engineering provide knowledge needed to establish the mobility society by going over the roles of urban activities and traffic. In Chapter 3, experts in environmental studies summarize the relationship between environmental issues and traffic and provide insight into the establishment of eco-friendly low-carbon societies.

From Chapter 4, the focus of the book shifts toward traffic-related issues and the characteristics and solutions of traffic jams are discussed by experts in traffic engineering. In Chapter 5, experts in information and communication engineering focus on the Intelligent Transport System as an advance in transportation technology and discuss its history and future development. In Chapters 6 and 7, mechanical engineering experts explain safe vehicle technologies by examining the factors in traffic accidents. In Chapters 8 and 9, medical professionals and psychologists explain the traffic-related psychology and behaviors of drivers and describe emergency medical care systems and accident prevention measures.

Traffic-related problems affecting the social system are addressed in Chapters 10 and 11. In Chapter 10, experts in law introduce traffic-related legal structures, criminal regulation, and risk management, while in Chapter 11, experts in economics describe sustainable growth while presenting conflicting concepts, such as balanced and unbalanced growth and regulation and deregulation. Lastly, under the Resilient mobility society heading, this book discusses how a mobility society should be prepared for and how to recover quickly from various disasters and socio-environmental changes.

In the Theory section, each chapter provides a listing of International Association of Traffic and Safety Sciences (IATSS) projects related to the respective chapter's contents. By reading the Practice section after the Theory section, readers can see how the theories address issues that pertain to specific areas.

It should be noted here that the aim of this book is not to exhaustively present professional opinions for each field. Rather, by going over each field in a cross-sectional manner, this book intends to help readers learn about traffic and safety sciences from a multifaceted perspective. Furthermore, the special interdisciplinary features of IATSS are strongly emphasized in this book, and it would be a great pleasure to see readers discovering new knowledge buried between chapters by reading each chapter and section freely.

Authors

Introduction

Kenji Doi — Professor, Department of Global Architecture, Graduate School of Engineering, Osaka University

Special features and application of this book

Akinori Morimoto — Professor, Faculty of Science and Engineering, Waseda University

Theory

Chapter 1 Cities and transportation

Kenji Doi — Professor, Department of Global Architecture, Graduate School of Engineering, Osaka University

Chapter 2 Transportation and land use

Akinori Morimoto — Professor, Faculty of Science and Engineering, Waseda University

Chapter 3 Transportation and the environment

Tomohiro Ichinose — Professor, Faculty of Environment and Information Studies, Keio University

Chapter 4 Traffic engineering

Takashi Oguchi — Professor, Institute of Industrial Science, The University of Tokyo

Chapter 5 Intelligent Transport Systems

Takaaki Hasegawa — Professor, Division of Mathematics, Electronics and Informatics, Graduate School of Science and Engineering, Saitama University

Chapter 6 The image of automobile safety

Taro Sekine — Associate Professor, Department of Mechanical Engineering, College of Science and Technology, Nihon University

Chapter 7 Technologies for safety improvement

Taro Sekine — Associate Professor, Department of Mechanical Engineering, College of Science and Technology, Nihon University

Chapter 8 Traffic psychology

Kazumitsu Shinohara — Professor, Graduate School of Human Sciences, Osaka University

Kazumi Renge — Professor, Department of Psychology, Faculty of Psychology, Tezukayama University

Chapter 9 Traffic safety and medicine

Kazuhiko Kibayashi — Professor, Department of Legal Medicine, School of Medicine, Tokyo Women's Medical University

Takashi Moriya — Professor, Emergency Department, Saitama Medical Center, Jichi Medical University

Masaya Takahashi — Senior Researcher, National Institute of Occupational Safety and Health, Japan

Chapter 10 Laws and policies pertaining to traffic safety

Makoto Saito — Professor, Graduate Schools for Law and Politics, The University of Tokyo

Hideaki Shiroyama — Professor, Graduate Schools for Law and Politics, The University of Tokyo

Takeyoshi Imai — Professor, Hosei University Law School

Toru Ogino — President, National Police Academy, Japan

Chapter 11 Sustainable growth—An economic perspective

Kazuhiro Ohta — Professor, School of Commerce, Senshu University

Mariko Futamura — Associate Professor, Department of Economics, Tokyo Woman's Christian University

Final thoughts Resilient mobility society

Yoshitsugu Hayashi — Professor and Director, Education and Research Center for Sustainable Co-Development, Graduate School of Environmental Studies, Nagoya University

Practice Written by each project leader

CONTENTS

Theory

Practice

Theory

Chapter 1
Cities and transportation

1.1 The dynamics of urbanization and the role of transportation

Cities change with the passage of time, moving from growth to decline. To make an analogy with human life, cities pass from periods of childhood to adolescence (urbanization), young adulthood to middle age (suburbanization), and into old age (disurbanization). However, cities also expect a fourth phase not comparable to human life, one of reurbanization.[1)] The form of urban transportation changes with the growth phase of the city, and the role of urban transportation changes as well according to the life cycle of the city as shown in Figure 1.

The role of transportation demanded in the urbanization phase is the carrying of large numbers of people into the city, for example by railways. During suburbanization, the emphasis is on moving people quickly over long distances. In the latter half of the suburbanization phase, the increasing development of low-density suburbs shifts the predominant modes of transportation toward private automobiles. Later in the disurbanization phase, increased spread of low-density urban areas (urban sprawl) causes a decline in public transportation created on the premise of mass transport, further increasing the dependence on automobiles. Many Japanese cities are still experiencing the effects of disurbanization (urban decline), but some cities are trying to proceed to the reurbanization stage. The role of transportation in this fourth stage is, in contrast to that during the suburbanization stage, connecting areas of agglomeration within the city at short distances and moderate speeds, and promoting interconnectedness between these areas of agglomeration.

The heavily automobile-dependent United States has been often called a “suburban nation.”[2),3)] However, the spread of road infrastructure and automobile use during the 20th century made it the “suburban era” for many countries worldwide. Those looking to escape from problems caused by increased urban density due to increasing populations looked to suburbs as a kind of utopia that would provide a wealthier countryside lifestyle, resulting in the mass production of largely uniform residential and commercial suburban development all over the world. Artificially planned suburbs with decentralized and individualistic lifestyles were supported by freedom of movement for private car owners, and later changed form into widespread sprawl development. This exacerbates the problem of automobile

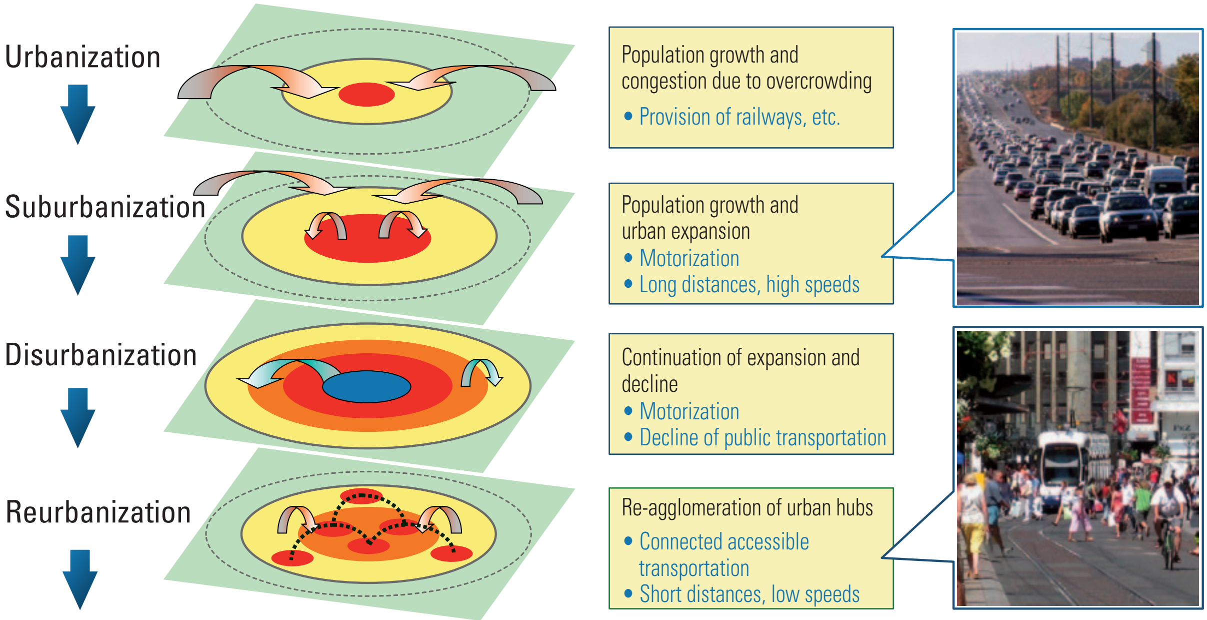


Figure 1. The urbanization process and the changing role of transportation

dependence, creating a negative synergistic effect between motorization and suburban sprawl.[4)]

The root of such urban and transportation problems is, in short, that our thinking regarding the role of transportation has halted at the suburbanization phase, considering that the goal of transportation must be "long distances, high speeds." We must evolve our thinking to the reurbanization phase, where the goal is rather "short distances, low speeds."

1.2 Mobility and accessibility

Mobility is generally defined as the ability to move, and according to Ota[5)] represents "the degree of freedom of general individual movement with no regard to specific destination." In contrast, accessibility refers to "the ability to perform demanding activities through movement to desired destinations." The word "accessibility" is also widely used in fields such as geography and transportation studies. Specifically, the word can also be defined to mean the ease of reaching destinations and opportunities such as workplaces, shopping, and medical services, or the ease with which one can make use of them. In recent years, accessibility and usability have come to be a

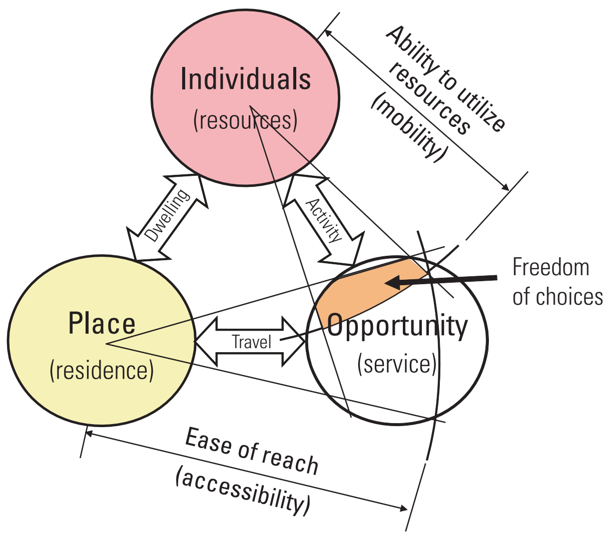


Figure 2. The relation between mobility and accessibility[6)]

central concept in ideas in universal design.[7)]

Figure 2 shows the relationship between mobility and accessibility in a schematic form for a single individual. Here, mobility is considered as the ability of an individual to make use of resources (time, money, external support and assistance, as well as environmental factors, etc.) through movement, and accessibility as ease of reaching essential opportunities and services. The perspective of mobility captures the degree of human-centered freedom of choices, while that of accessibility captures the degree of place-based freedom as relating to the places that attract people. Our overall freedom of choices is determined by both mobility and accessibility.

1.3 Urban travel speed and safety

At the national level, emphasis should be placed on fast mobility to connect cities and hubs at high speed by the latest technologies, including a maglev Shinkansen and a logistics Shinkansen for the country's high-speed rail network. On the other hand, slow mobility for enjoying excursions and interactions at a safe and comfortable speed should be emphasized for personal and social reasons at the local level. Rigid differentiation of travel speed according to location is required for achieving sustainable transportation as well as increasing the attractiveness of cities.

In Japan, which is experiencing the problems of population decline and super-aging of society, large-scale shrinking of cities is required from the perspective of national land and urban management. However, such severe constraints can also serve to foster creativity that can break through the impasse and lead to co-evolution of transportation, urban, and social developments. The development of "shrinking cities" to achieve sustainability and the development of "creative cities" to increase competitiveness are strategies that are two sides of the same coin, and the realization of both will require a reconfiguration of the bonds between the elements of people, knowledge, goods, services, money, and time. Mobility is the key to doing so. As mentioned in Section 1.2, mobility refers both to freedom of movement and ability to make use of resources.

Building a mobility system for cities that are both sustainable and highly competitive will require a multifaceted understanding of the value of mobility, along with the formation of a hierarchical network, consisting of a fast mobility layer that connects cities and hubs at high speed and a slow mobility layer within cities and hubs that promotes excursions and interactions at low to medium speeds. Slow mobility refers to means and forms of transportation at near-human speeds. But why is such distinction between speeds necessary?

A negative aspect of motorization is its standardization of travel speed. Whether in towns, suburbs, or between cities, most automobile drivers pursue speed. The desire for "long distances, high speeds" mentioned in Section 1.1 is ever-present, whether one is inside or outside of urban areas.

The pursuit of speed regardless of places results in uniform expansion that impairs the hierarchy of urban spaces. The result is longer daily trips to work and school, increased energy consumption for transportation, increased production of CO_2 and local environmental load, and even threats to life due

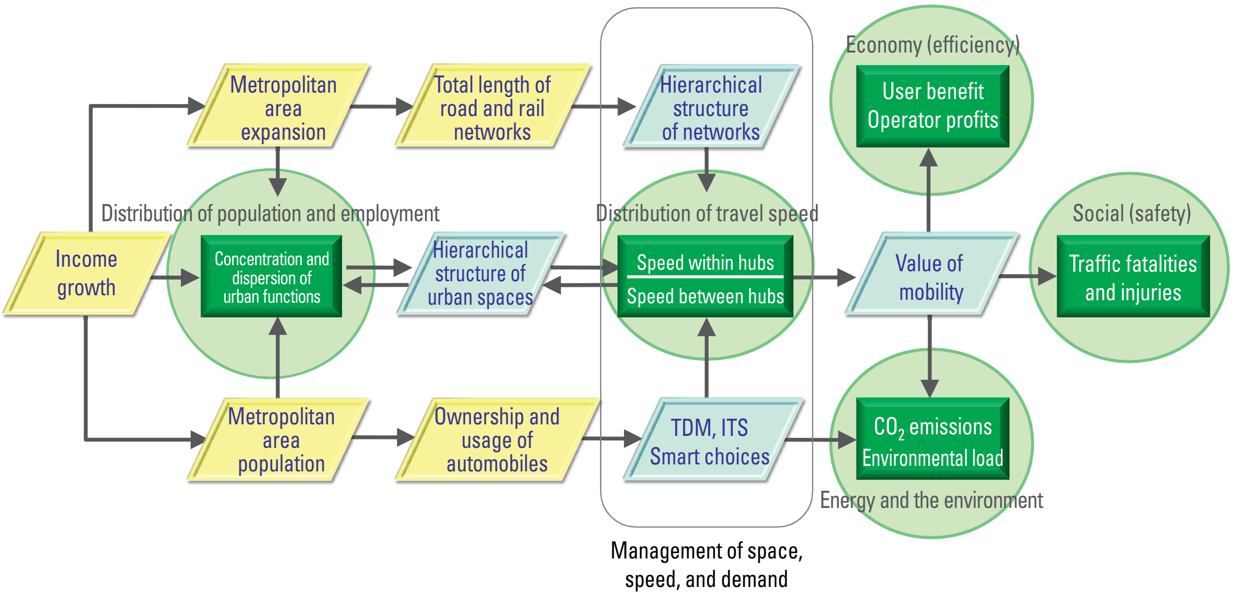
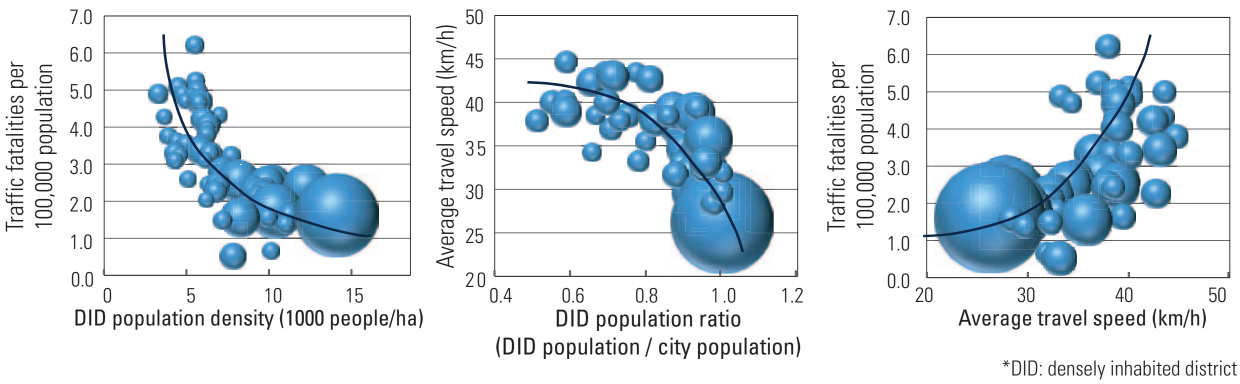


Figure 3. A causal relationship regarding the value of mobility and travel speed as the key factor

to increased risk of injury or death in a traffic accident (Fig. 3).

Figure 4 shows the relationship between urban population density, automobile travel speeds, and rates of road traffic deaths between 2008 and 2010 for 65 regional core cities with a population over 300,000 inhabitants in Japan. Bubble size in the figure represents the population of the city. From Fig. 4 (a), one can clearly see that the rate of traffic fatalities increases with lowered urban density. Considering that this relationship may vary between cities due to differences in the development level and usage rates of urban public transportation, we focused on only automobiles and analyzed the relationship between population distribution and average automobile running speed for intra-city travel, as well as the relationship between average travel speed and traffic death rate. As the results in Figs. 4 (b) and (c) show, we found causal relationships in which the more two-dimensionally dispersed a city was, the higher its average automobile travel speed, and the higher the average travel speed, the higher the traffic death



(a) Population density and road traffic death rate (b) Population distribution and average automobile travel speed (c) Average travel speed and road traffic death rate

Figure 4. Urban population density and distribution versus average automobile travel speeds and rates of road traffic deaths

rate.[8)] These results consider only the relationship between density, speed, and safety, so in the future there is a need to analyze the effects of travel speed on society, the economy, and the environment, while keeping in mind the causal relationships indicated by Figure 4.

One result of increasingly slower movement speeds in urban areas and pursuit of the merits of slow mobility is the cycling revolution currently spreading in Europe. As shown in Figure 5, for trips up to around 5 km bicycles have a quicker travel speed than do automobiles and trains, and as is well known in Japan bicycles serve as an excellent, efficient and fast transportation mode within cities. The cycling revolution in London is famous for results such as its cycle super-highways and cycle hire (bike-sharing) scheme, but the social background and events leading up to this realization is rich in lessons. A series of socioeconomic factors such as soaring fuel prices starting around 2002, the introduction of in-town road pricing in 2003, and subway and bus terrorist attacks in 2005 are some of the influences that led people to use bicycles for their travel needs.

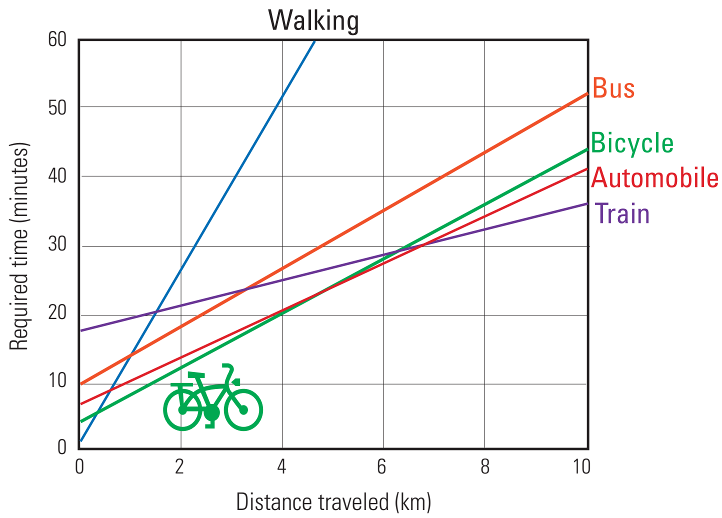


Figure 5. Comparison of travel times by transportation mode for intra-city travel

1.4 Aging and travel needs

As humans age they experience changes in physiological functions, reduced physical ability, reduced cognitive characteristics, and other changes in psychology and awareness that cause a decline in movement ability (Fig. 6). Figure 7 shows some of these mental changes that accompany increased age and result in changes in travel needs.

In particular, the elderly place less weight on the time and cost aspects of travel, and more weight on travel that is safe, secure, and beneficial to health and the environment. When this is displayed as a ternary plot showing the positioning of various modes of transportation, the travel needs in an aging society show a clear shift up and to the right, representing a shift toward demand for medium- to

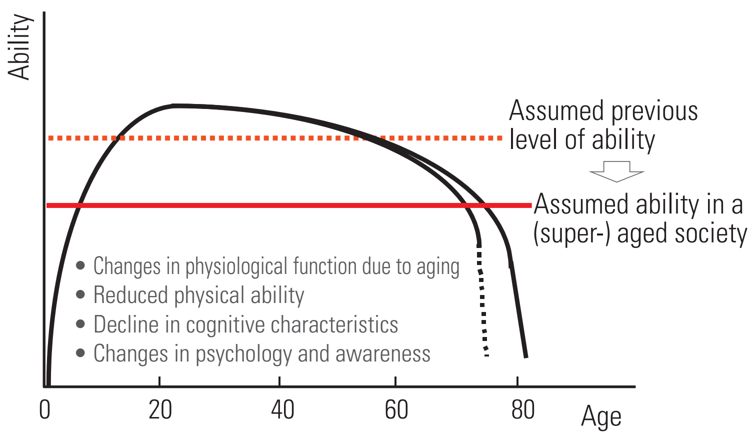


Figure 6. Changes in human ability accompanying age

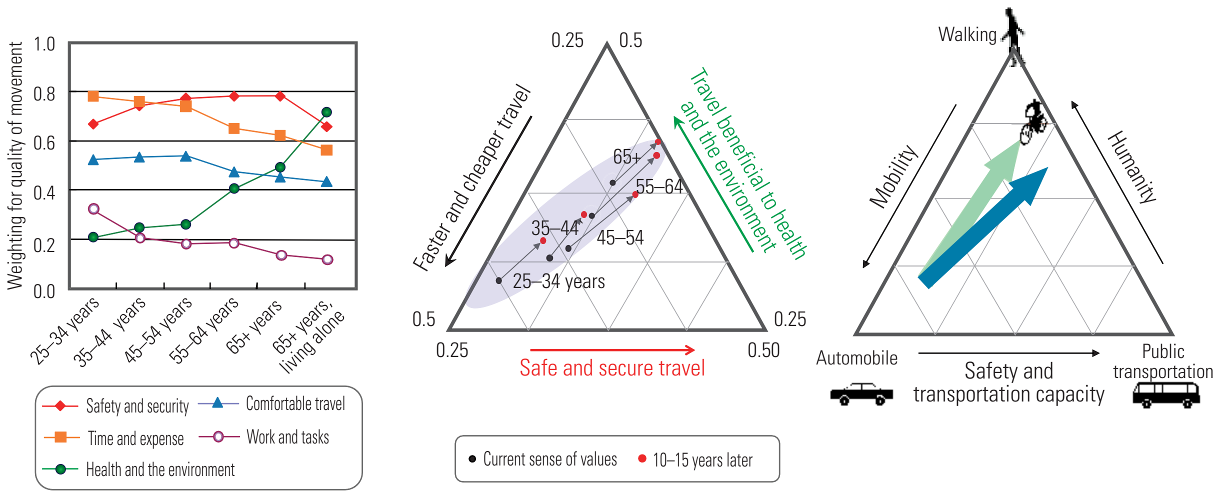


Figure 7. Changes in travel needs accompanying aging[9), 10)]

low-speed "slow mobility" that is located in the position between public transportation and private transportation. This is the position associated with transportation modes such as next-generation LRT systems, low-speed electric community buses, community cycles, and other forms of shared personal mobility.

Building the mobility system for a sustainable city will require a bold outlook on making these changes, and enhanced safety is the starting point of the change process. Doing so will require making decisions on the priorities for and extensive management of speeds of road transportation. Efforts to achieve the harmonious coexistence of humans and automobiles through reducing speeds can be seen in European speed management programs such as the establishment of the "Zone 30" measure, which establishes establish a 30 km/h (20 mph) zone. In recent years there have been increased efforts toward retaining comfortable space via improved road design that attempts to change driver behavior in ways that reduce their running speed. There has also been a worldwide trend toward promoting "walkable cities," which allow residents to walk to places necessary for daily life. These are some examples in which human-centered prioritization has been established as the guiding principle for road and urban space design.

1.5 Integrated design of cities and transportation

The term "integrated transportation" came into common use in the latter half of the 1990s. It goes without saying that a unified perspective is needed when developing transportation policy. The most important point is that one performs not an additive unification, but an integrated approach that combines diverse aspects into a whole. There are four levels in a desirable integrated transportation system:

1) *Operational integration*: integration of public transportation services, fare structures, and operation information
2) *Strategy integration*: integration of policy instruments for the infrastructure, management,

information provision, and pricing between different transportation modes

3) *Policy integration*: integrated policies for transportation and land use; integrated policies between transportation divisions and divisions for other areas such as the environment, health care, social welfare, education, and disaster prevention

4) *Organizational integration*: integration of the various organizations and institutions that are responsible for transportation

Of the above, integrated transportation and urban design largely correspond to item 3), policy integration. In compact cities aiming for sustainability, as well as in transportation systems developed considering the needs of an aging society, addressing each of these in isolation will result in diminished effects. The expansion of cities seen in the twentieth century resulted from increased motorization and road development extended to far-reaching suburbs, in addition to population growth pressures. At a minimum, therefore, it is imperative to perform policy design of integrated transportation and urban development.[11), 12)]

Figure 8 shows some of these integrated design concepts and procedures. The figure illustrates the relation of the four domains of city, infrastructure, mobility, and society; mobility is centrally located and is positioned as a system in which public transportation and personal mobility measures complement each other. "Road diets" refers to a method for creating space for pedestrians, bicycles and other medium- to low-speed personal transportation modes by reducing the number and/or width of roadway

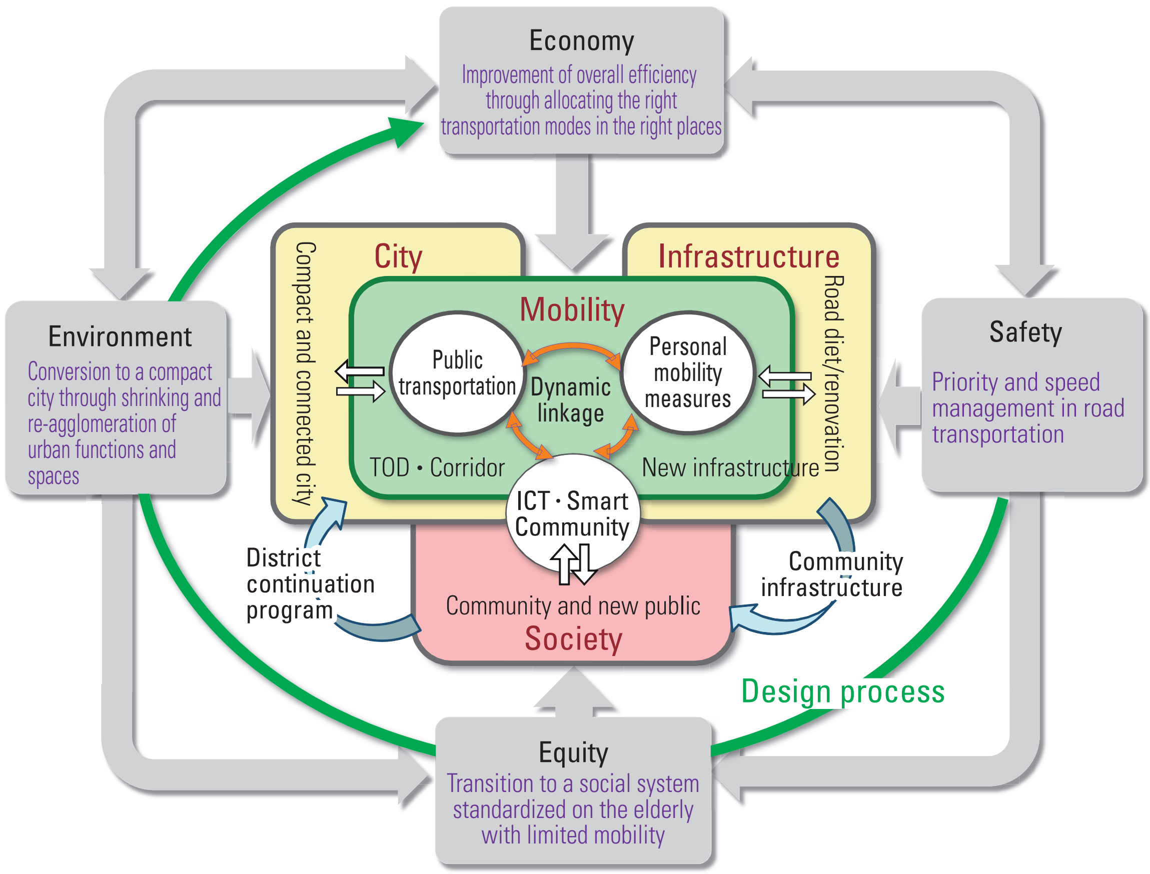


Figure 8. Integrated design of cities and transportation

lanes. This allows existing roads renovated with an emphasis on the usability of road spaces by a broader range of users, and has already been implemented in many countries. In addition, transit-oriented development and corridor development are methods of supporting public and shared transportation from a land use aspect. Detailed discussions of these are presented in chapter 2.

As the design process loop in the figure shows, priority-based road space allocation and strict speed management to secure traffic safety are the primary pursuit, and they result in the ability to render social systems standardized on the elderly in which universal design can assist in providing increased accessibility. Also promoted is a conversion to compact cities in which urban functions and spaces are more aggregated. When these conditions are met, regional public transportation becomes sustainable, and the strategy of "allocating the right transportation modes in the right places" will lead to improved overall efficiency. Implementing a mobility revolution will be impossible without holistic perspectives that clearly prioritize management of speeds (slowness) and spaces (compactness), as well as time management that harnesses the opportunities and threats of external shocks and constraints, converting these to revolutionary force. In Japan, there are continued trends for neglecting the global optimization in transportation policy; public transportation policy is still being discussed in isolation, and slow mobility modes such as bicycles are positioned merely as local solutions without intermodal integration.

In a future of increasingly harsh economic and financial conditions, it will be difficult to improve the quality of mobility in a super-aged society without meeting prerequisites of priority, slowness, and compactness (PSC). Quality of mobility refers to social usability for users with diverse needs. Moving beyond the physical, physiological, and ease-of-use levels of today's "usable" mobility systems to a higher level in which one psychologically wants to use the system will require a revolutionary process that emphasizes PSC.

The view of linear growth that aims at an American- or European-style society has become less effective.[13)] Nevertheless, we find it difficult to abandon such concepts of growth in our pursuit of a future mobility society. This is why our thinking on the role of transportation comes to a halt as described at the beginning of this chapter. The development of a mobility society best suited to ourselves will require consideration of not only technologies and systems, but also culture and ethos.

References

1) Klassen, L. H., J. A. Bonrdrez, and J. Volmuller. 1981. *Transport and Reurbanisation*. Gower.
2) Duany, A., E. Plater-Zyberk, and J. Speck. 2000. *Suburban Nation: The rise of sprawl and the decline for the American Dream*. North Point Press.
3) Hall, P. 1996. *Cities of Tomorrow*. Blackwell Publish Ltd.
4) Hayashi, Y., R. Suparat, R. Mackett, K. Doi, Y. Tomita, N. Nakazawa, and H. Kato. "Urbanization, motorization and the environment nexus: An international comparative study of London, Tokyo and Bangkok." *Memoirs of the School of Engineering, Nagoya Univ*. Vol. 46, No. 1: 55–98.
5) Ota, K. 1988. *Kotsu shisutemu keikaku* [Transportation system plan]. Gijutsu shoin (in Japanese)
6) Doi, K., H. Nakanishi, M. Kii, and I. Sugiyama. 2006. "Examining policy implications of location efficiency as a key concept in TOD implementation." *Journal of JSCE(D)* Vol. 62, No. 2, 207–212. (in Japanese)
7) Alshih, R., and D. Hensher. 2003. "The mobility and accessibility expectations of seniors in an aging population." *Transportation Research Part A* Vol. 37 (A): 903–915.

8) Doi, K. 2013. "Suro mobiritei" [Slow mobility]. *International Journal of Automotive Engineering* Vol. 67, No. 3, 24–31. (in Japanese)
9) Doi, K., T. Hasegawa, S. Kobayashi, I. Sugiyama, M. Mizohata. 2011. "A Study on 'Quality of Mobility' Demanded in Super-aged Cities." *IATSS Review* Vol. 35, No. 3: 38–49. (in Japanese)
10) Doi, K. 2011. "Komobiritei ga michibiku kotsu to toshi no kyohatten" [Co-mobility leading to transportation and social developments] *Japan Railway Engineer's Association* Vol. 54, No. 7: 4–6. (in Japanese)
11) Hayashi, Y., K. Doi, H. Kato, and International Association of Traffic and Safety Sciences, eds. 2009. *Toshi no kuoritei sutokku: Tochi riyo, ryokuchi, kotsu no togo senryaku* [Quality Stock of Cities: Integrated strategy of land use, green space and transportation]. Kajima Institute Publishing. (in Japanese)
12) Doi, K., and M. Kii. 2012. "Looking at sustainable urban mobility through a cross-assessment model within the framework of land-use and transport integration." *IATSS Research* Vol.35: 62–70.
13) Takeuchi, K. 2014. "The ideal form of transdisciplinary research as seen from the perspective of sustainability science, considering the future development of IATSS." *IATSS Research* Vol.38.

Recommended Reading
1) Alonso, W. 1964. *Location and Land Use*. Cambridge MA: Harvard University Press.
2) Anas, A. 1982. *Residential Location Markets and Urban Transportation: Economic Theory, Econometrics and Policy Analysis with Discrete Choice Models*. New York: Academic Press.
3) Banister, D. 2003. *Transport Planning: In the UK, USA and Europe*. Routledge.
4) Batty, M. 1994. "A chronicle of scientific planning: the Anglo-American modeling experience." *Journal of the American Planning Association* 60: 7–16.
5) Berechman, J., and K. A. Small. 1988. "Modeling land use and transportation: an interpretive review for growth areas." *Environment and Planning A* 20: 1283–1422.
6) Boarnet, M. G., and R. Crane. 2000. *Travel by Design: The Influence of Urban Form on Travel*. New York: Oxford University Press.
7) Calthorpe, P. 1993. *The Next American Metropolis*. New York: Princeton Architectural Press.
8) Cervero, R. 1989. *America's Suburban Centers: The Land-use-Transportation Link*. Unwin Hyman.
9) De la Barra, T. 1989. *Integrated Transport and Land Use Modeling: Decision Chains and Hierarchies*. Cambridge University Press.
10) Dunham-Jones, E. 2011. *Retrofitting Suburbia, Updated Edition: Urban Design Solutions for Redesigning Suburbs*. Wiley.
11) Grant, J. 2006. *Planning the Good Community: New Urbanism in Theory and Practice*. London: Routledge.
12) Hall, P. 2002. *Cities of Tomorrow*. Wiley.
13) Hensher, D. A., K. J. Button, K. E. Haynes, and P. R. Stopher, eds. 2004. *Handbook of Transport Geography and Spatial Systems*. Elsevier.
14) Howard, E. 2010. *To-morrow: A Peaceful Path to Real Reform*. Cambridge University Press.
15) Iacono, M., D. Levinson, and A. El-Geneidy. 2008. "Models of transportation and land use change: a guide to the territory." *Journal of Planning Literature* 22 (4): 323–40.
16) Irwin, E. G. 2010. "New directions for urban economic models of land use change: incorporating spatial dynamics and heterogeneity." *Journal of Regional Science* 50: 65–91.
17) Jacobs, J. 1992. *The Death and Life of Great American Cities*. Vintage.
18) Jenks, M., and N. Dempsey. 2005. *Future Forms and Design for Sustainable Cities*. Routledge.
19) Lynch, K. 1981. *Good City Form*. Cambridge MA: MIT Press.
20) Mees, P. 2009. *Transport for Suburbia: Beyond the Automobile Age*. Routledge.
21) Newman, P., and J. Kenworth. 1999. *Sustainability and Cities: Overcoming Automobile Dependence*. Island Press.
22) Simmonds, D., P. Waddell, and M. Wegener. 2013. "Equilibrium versus dynamics in urban modelling." *Environment and Planning B: Planning and Design* 40 (6): 1051–1070.
23) Speck, J. 2012. *Walkable City: How Downtown Can Save America, One Step at a Time*. Farrar, Straus and Giroux.
24) Vuchic, V. R. 2005. *Urban Transit: Operations, Planning and Economics*. Wiley.
25) Waddell, P. 2002. "UrbanSim: Modeling urban development for land use, transportation and environmental planning." *Journal of the American Planning Association* 68: 297–314.
26) Walker, J. 2011. *Human Transit: How Clearer Thinking about Public Transit Can Enrich Our Communities and Our Lives*. Island Press.

27) Webster, F. V., and N. J. Paulley. 1990. "An international study on land-use and transport interaction." *Transport Reviews* 10: 287–322.
28) Wegener, M. 1982. "Modeling urban decline: a multilevel economic-demographic model of the Dortmund region." *International Regional Science Review* 7: 21–41.
29) Wegener, M. 1994. "Operational urban models: state of the art." *Journal of the American Planning Association* 60: 17–29.
30) Wilson, A. G. 1997. "Land use/transport interaction models: past and future." *Journal of Transport Economics and Policy* 32: 3–23.

Practical application projects for reference

A land utilization framework and transportation system for declining population: 132–135
Quality of mobility required for super-aged cities: 136–139

Chapter 2
Transportation and land use

2.1 The relationship between land use and transportation

Understanding the relationship between land use and transportation is extremely important for designing a prosperous and safe transportation society.[1)]

Land use and transportation are interdependent, similar to a chicken-and-egg relation. Effective utilization of land stimulates urban activities, and roads and other transportation facilities are maintained so as to allow for new transportation-related activity. Creating new roads or expanding existing ones increases the attractiveness of the land they pass through, promoting new urban facilities. When cities are growing slowly, it is easy for land utilization and traffic planning to match pace. In times of rapid economic growth, however, demand for land use accelerates and development of transportation facilities may be unable to keep up. Many cities experiencing a high degree of economic growth will therefore experience heavy congestion and other transportation problems.

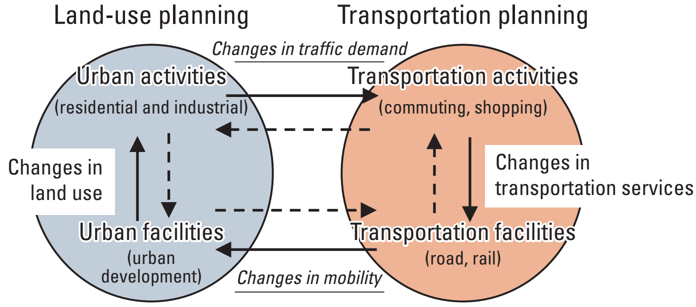


Figure 1. Relation between land use and traffic planning

How can the best balance be maintained between land use and transportation? Japan experienced a period of rapid motorization, a time during which it was impossible to keep up with demands for road expansion and other transportation facility development, and therefore implemented policies to regulate transportation demand itself. Such policies are called transportation demand management (TDM). Examples of TDM include changing peak demand times and shifting demand to other modes of transportation, thereby enabling existing roads to be utilized to the fullest extent possible.

An even more fundamental approach is promoting optimal land use. For example, when transportation facilities are poor, the floor area ratio can be kept low and then the ratio can be increased according to the progress of transportation infrastructure development. Efforts can thus be made to achieve a balance. Long-term sustainability should also be considered by altering the urban structure itself. For example, transportation demands that are concentrated in downtown areas can be dispersed to city sub-centers and core cities, thereby relieving congestion and promoting development of a more balanced city overall. Such efforts in Tokyo and other large cities have been implemented as the construction of multi-polar, distributed urban structures. The Third National Capital Region Development Plan (1976), for example, recommends a more wide-area, multipolar distribution to correct Japan's over-concentration on Tokyo, and the follow-up Fourth Development Plan (1986) suggests prioritizing development of business core cities and secondary core cities with the goal of creating a more multi-zonal, multi-nuclear urban structure.

There are differences in the emphasis placed on transportation problems such as congestion, noise, and air pollution, depending on the region and era. Having entered the 21st century, the traffic problems currently facing Japan, such as adapting to becoming a super-aged society and addressing global environmental issues, reflect increasingly long-term, wide-area considerations. However, even for such new problems, considering land use and transportation planning over time can lead to finding solutions to a variety of transportation problems so as to meet the needs of the future.

What kind of urban structure should be aimed for, and by what method should such an urban structure be developed? What kind of transportation facilities will be emphasized at that time? How should the remaining localized congestion be addressed? In this section, how developed countries are addressing such issues is examined in order to learn about four keywords necessary in urban development for the next generation.

2.2 Compact cities

2.2.1 Why are compact cities needed?

The question of how to plan and aggregate urban areas that have expanded with the progress of motorization so that they can be converted to sustainable cities is a significant problem that faces mature societies. In Japan, which has entered an era of population decline, intelligent reduction in the scale of now unneeded urban areas ("smart shrinking") has become an urgent task. In the Second Report of the Panel on Infrastructure Development (2007), the following problems may arise when the structure of diffuse cities is left unaddressed:

- Difficulty in maintaining public transportation: It is difficult to ensure demand for public transportation in low-density cities.
- Problems with transportation in a super-aged society: There will be an increased number of transportation-disadvantaged individuals who cannot operate automobiles.
- Increased environmental load: Excessive reliance on automobiles increases environmental load.
- Further decline of central urban areas: Promotion of suburban development causes a relative decline in the attractiveness of urban areas within cities.

- Pressures on municipal finances: Increased maintenance costs of expanded urban areas.

Even in developing countries experiencing economic growth, inducing urban structures that are appropriate to periods of population increase is important for avoiding problems seen in developed countries.

2.2.2 What is a compact city?

A compact city is one in which functions required for daily life are aggregated in the city center, and one with a maintainable city structure that retains an appropriate population density while remaining resident-friendly and environmentally friendly. In periods of population growth there is a tendency for urban areas to encroach on green spaces, while in periods of population decline there is a tendency for green space to expand into urban areas. It is hoped that this will lead to an appropriate scale reduction of the city itself. In particular, it is important that aggregation along public transportation lines strikes a proper balance between the use of automobiles and public transportation.

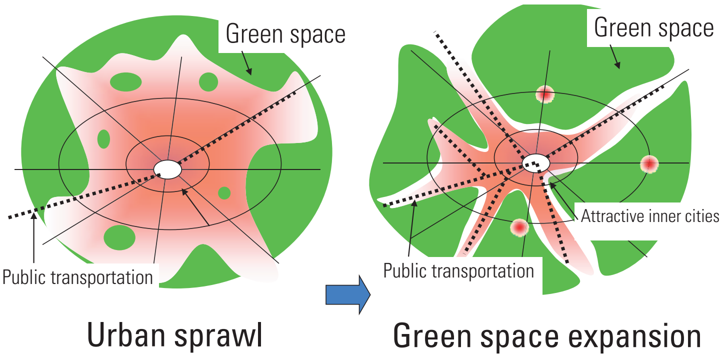


Figure 2. Smart shrink

2.2.3 Proposal for network-type compact cities

Compact cities first attracted attention when they were proposed in the 1987 Brundtland Report as an urban model for sustainable development. Such cities aim at an environment that promotes public transportation and walking, and avoids over-reliance on privately owned automobiles. However, it is extremely difficult for cities to aggregate once they have expanded, and although local governments may establish urban planning master plans as goals, achieving such goals requires a long time. Escape from low-density, automobile-oriented urban structures cannot be achieved without further urban planning that features public transportation as its core. Here, we propose the "network-type compact city,"[2)] based on transit-oriented development (TOD), which is

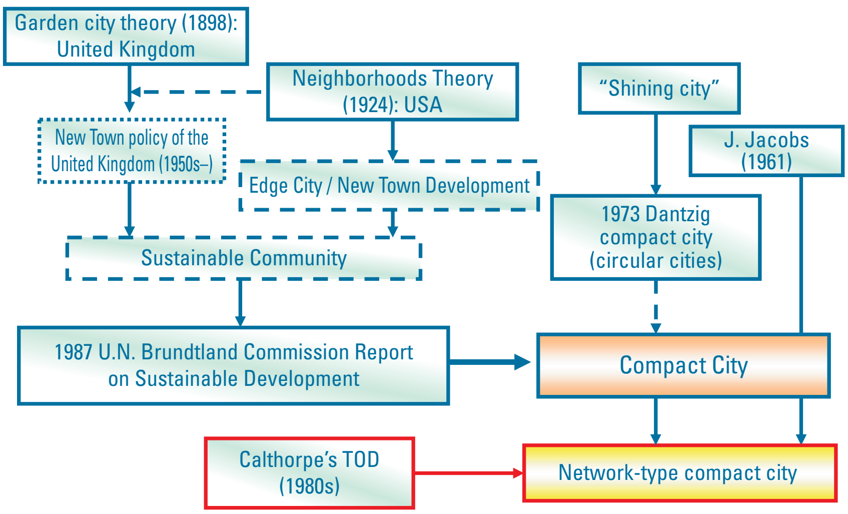


Figure 3. A genealogy of network-type compact cities

described below.

A network-type compact city is one in which the various attractive features of the city are aggregated (compacted) in multiple areas that are connected (networked) by various modes of transportation, with a focus on highly convenient public transportation. Figure 4 shows the structure of such a city. In this context, the word “compact” does not necessarily mean concentration at a single point but rather efficient aggregation over multiple hubs. One feature of network-type compact cities is that they have disaster resilience. Ensuring redundancy through the interconnection of multiple hubs of aggregation means that even if one part of the city is affected by a disaster, resilience of the city overall is increased because other areas can flexibly participate in recovery efforts.

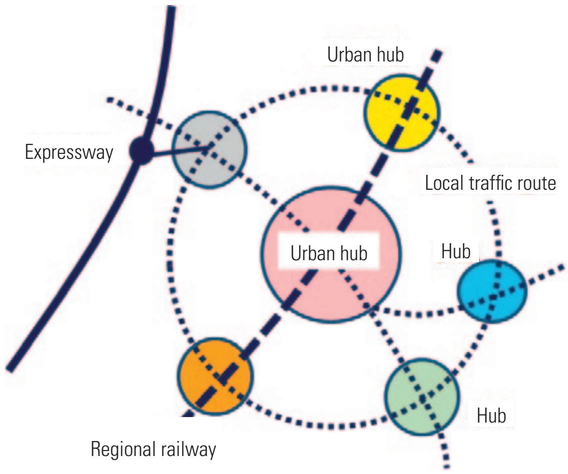


Figure 4. A network-type compact city

2.3 Transit-oriented development (TOD)

2.3.1 The pros and cons of automobile-dependent city development

In times of rapidly increasing urban population, cities suffer from shortages of residential areas, which leads to the development of many large-scale suburbs. Railway lines are often developed in large suburban cities, and further increase with the expansion of public transportation networks. Very different from the development of regional cities, the development of suburbs is often done regardless of the convenience of public transportation, greatly increasing reliance on automobiles. Furthermore, commercial development often occurs on the assumption of high automobile utilization, resulting in continued development in areas along suburban bypass routes, spurring the decline of central urban areas.

The automobile is indeed a comfortable and convenient mode of transportation, but over-reliance on automobiles detracts from other modes of transportation, and leads to the building of a society that is unfriendly toward transportation-disadvantaged residents who do not own an automobile. Learning from this, developed countries are turning their attention toward urban planning that focuses on public transportation.

2.3.2 What is TOD?

TOD means urban development that is centered on public transportation and avoids over-reliance on automobiles. Its fundamental concepts were proposed in the 1980s by Calthorpe, but precursors to this

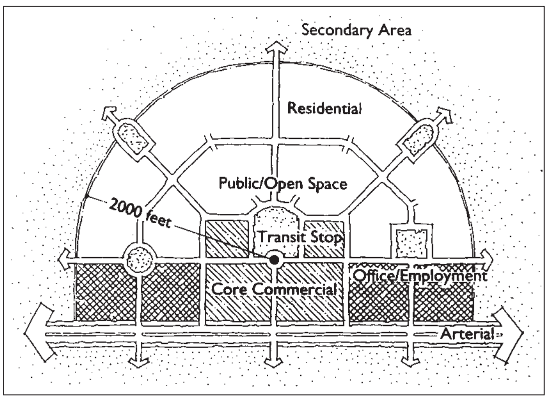


Figure 5. Conceptual diagram of TOD (P. Calthorpe)[3]

concept can be seen in Japan in the development of areas around train stations, promoted by private railway companies since before World War II. Such development aimed at city planning in which commercial, industrial, and residential functions were situated in an area within 600 m from train stations, allowing a walking-based lifestyle.[4)]

TOD is performed with an emphasis on three important elements, called the three D's: [5)]

Figure 6. San Francisco (Fruitvale Transit Village)

Density: Maintenance of public transportation requires ensuring a certain degree of population density. That degree will vary somewhat depending on regional characteristics, but in general planning should ensure that population density does not go below 40 persons per hectare.

Diversity: It is important that commercial, medical, welfare, and other public functions be aggregated around train stations, so that basic life activities can be performed within walking distance.

Design: Good spatial design is vital to inducing land use. Attractive spaces have an effect on how people choose where to live.

2.3.3 Urban area aggregation through implementation of TOD

Cities are connected with other cities by rapid rail systems and other forms of high-speed public transportation, and the downtown areas of those cities are connected to their suburbs by light rail transit (LRT) and bus rapid transit (BRT) systems, thus providing public transportation that is both punctual and fast. TOD is mainly implemented along such public transportation routes.[6)] Providing high levels of public transportation service in such areas over a long period of time and in a punctual manner promotes urban aggregation. In contrast, in suburban areas experiencing population decline, variable public transportation systems such as demand response transit (DRT) are implemented.

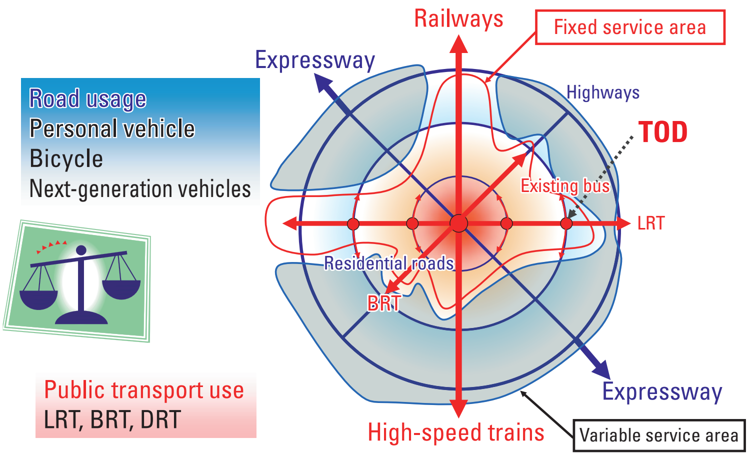


Figure 7. Urban space design implementing TOD

Transportation-disadvantaged residents such as the elderly are encouraged to live in TOD areas, while large families who most greatly benefit from the utility of automobiles are encouraged to raise their children in the green-rich areas of the suburbs. Selection of residential areas according to lifestyle thus allows for urban planning that best accommodates all generations.

2.4 Next-generation public transportation systems

2.4.1 Reconstruction of the hierarchical nature of urban transport

In many regional areas, trends toward excessive reliance on automobiles have led to cities in which the only means of transport in and out of the city is by automobile. This has led to significant destruction of the traditional hierarchical nature of urban transport, such as through-traffic encroaching into residential areas and bus companies being forced to close routes. Development of a society that is environmentally friendly and compatible with a super-aged society requires the urgent reconstruction of a transportation system that does not rely on automobiles alone.

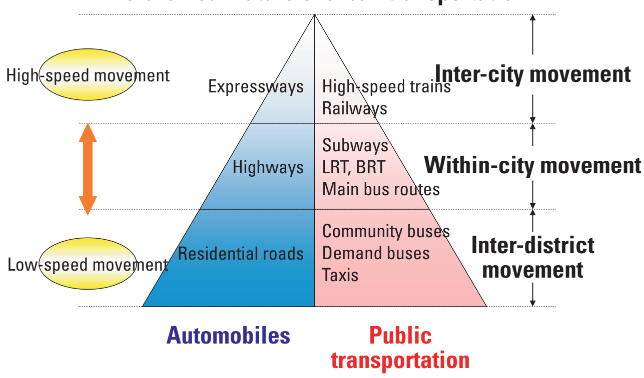


Figure 8. Hierarchical nature of urban transportation

Desirable next-generation transportation systems must strike a balance between automobiles and public transportation, through a hierarchical differentiation of transportation functions. Considering automobile traffic, this hierarchy forms a pyramid with highways that maximize traffic functionality at the top and highly accessible nearby residential roads at the bottom. Similarly, with regards to public transportation the pyramid has rapid rail transit that allows high-speed movement between cities at the top and community-level bus services that allow movement between districts at the bottom. As one works toward the bottom of the pyramid, transportation speed decreases while flexibility of service increases.

2.4.2 Functionality of next-generation public transportation systems

Revitalizing public transportation systems in cities in decline will require improving comfort and convenience. To that end, the following functions are required:

Punctuality: The system should not be affected by traffic congestion, such as through the use of traffic lanes dedicated to public transportation.

Comfort: Transportation should be elderly-friendly, for example, by having little vibration and being barrier-free.

Environmentally friendly: The system should consume little energy, and minimize noise and pollutant emissions.

Attractiveness: Vehicles and pick-up locations should contribute to city planning by being suited to the landscape.

The most important thing is that the system draws riders away from their automobiles and provides sufficient added value to alter land use along routes.

2.4.3 LRT and BRT

Examples of public transportation systems that contain the above-mentioned functionality are next-generation LRT and BRT systems.

In contrast to heavy rail systems that provide transportation between cities, LRT systems provide transportation within a city. In Japan, these often take the form of next-generation tram systems. They are characterized by having improved functionality over older tram systems, being better integrated with other modes of transportation, and contributing to urban development by functioning as a comprehensive transportation system. The first LRT system was developed in Edmonton, Canada, in 1978. Since then, LRT systems have been introduced in 111 cities (as of 2008) throughout the world.[7)]

BRT systems provide large-scale, rapid transport of passengers by bus. Unlike traditional bus routes, these systems use dedicated traffic lanes to allow frequent and punctual service, which can in some situations improve transportation capacity through the use of articulated vehicles and allow for smoother boarding at dedicated stops. Such systems are already in place in locations such as Ottawa (Canada), Curitiba (Brazil), and Bogota (Columbia).

A common feature between both systems is that they are introduced not as isolated methods of transportation, but as one facet of a sustainable mobility system suited to next-generation cities. Such attractive public transportation systems are expected to be effective at promoting better and more aggregated land use.

Figure 9. LRT in Houston

Figure 10. BRT in Curitiba

2.5 Large-scale development and transportation assessment

2.5.1 Traffic problems caused by large-scale development

In recent years, intensive land use and progress of the automobile society has brought about large-scale development not only in cities but also in their suburbs. Traffic generated by new development is extremely heavy and has an effect over a wide area. The regions surrounding newly developed areas frequently already have a considerable amount of traffic demand, resulting in road congestion in some areas, so new developments have a high risk of further intensifying congestion, accidents, pollution, and other transportation-related problems. So what methods are there for easing chronic traffic congestion, while still maintaining a balance between land use and transportation? This section describes one basic method, traffic assessment for large-scale development.

2.5.2 What is a traffic assessment?

Traffic impact assessments, or simply traffic assessments, are a method and system for assessing in advance the effects of development plans on transportation in order to implement traffic policy from the perspective of harmonizing land use and transportation.

In a broad sense, traffic assessment is a macro-level approach for controlling land use patterns, density, and urban traffic master plans. In a more narrow sense, it can be applied as a micro-, district-level approach, which in Japan has been implemented for development exceeding a certain scale by the Ministry of Land, Infrastructure and Transport's "Large-scale Development District-related Traffic Planning Manual," by the Ministry of Economy, Trade and Industry's "Large-Scale Retail Stores Location Law," and by public safety commissions or traffic administrators' "prior traffic measures". Generally speaking, "transportation assessment" refers to the narrower definition.[8)]

2.5.3 Proper provision of parking lots for areas of large-scale development

When performing large-scale development, it is necessary to provide adequate parking that is commensurate with the traffic demand. For example, the Large-Scale Retail Stores Location Law requires that a person who establishes large retail stores secure an adequate number of parking spaces.

The number of necessary parking spaces is determined by using an equation that takes the number of customers, peak ratio, car ownership ratio, parking lot usage time, and other factors as parameters. It is important to verify at the development assessment stage that an appropriate number of parking spaces will be available.

$$X = \frac{A \times S \times B \times C \times E}{D}$$

A: Number of daily customers by store floor space (persons/1000 m^2)
S: Store floor space (1000 m^2) B: Peak ratio (%)
C: Car ownership ratio (%) D: Average number of car passengers (persons)
E: Average parking time coefficient

2.5.4 Traffic simulations for large-scale development

It is extremely important in traffic assessment to grasp traffic conditions quantitatively and in detail. Innovations in information technology since the 1990s have resulted in dramatic improvements to computer processing capabilities, allowing detailed, second-scale reproduction of traffic conditions and visual representations as animations, including signal controls, traffic lane construction, and other aspects. As result, many traffic simulators have been developed and practically implemented both in Japan (tiss-NET,

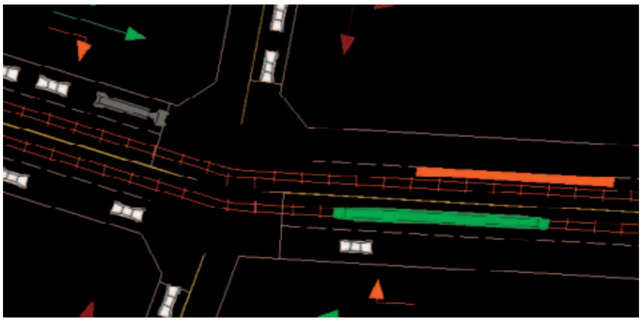


Figure 11. Traffic simulation screen

AVENUE, TRAFFICSS, VISITOK, etc.) and overseas (NETSIM, Pramics, WATSim, etc.).

Table 1. Conditions of the traffic simulations in Tochigi Prefecture

Peak arriving vehicles	Relation between lot shape and traffic	
	No risk of congestion	Risk of congestion
200–600 vehicles (100 vehicles per direction)	Not needed	Needed
600 or more vehicles	Needed	

Developing traffic simulations requires substantial time and effort, so application conditions need to be publicly documented. Consideration of traffic simulations from early stages allows those wishing to open stores to apply them to site selection. Table 1 shows the implementation conditions for a traffic simulation performed in Tochigi prefecture.

From these results, merchants, road managers, and traffic control personnel can consider the effects of congestion reduction policies before the establishment of large-scale stores. Note that there are many significant effects of large-scale development, and in situations where mitigation measures are difficult through transportation facility development, reconsideration of site selection for large-scale development may become necessary.[9)]

References

1) Sugiyama, Masahiro, Sotaro Kunihisa, Mitsuyuki Asano, and Hirohito Kuse, eds. 2003. *Asu no toshi kotsu seisaku* [The Future of Urban Transport Policy]. Seibundo Publishing. (in Japanese)
2) Morimoto, A. 2012. “A preliminary proposal for urban and transportation planning in response to the Great East Japan Earthquake.” *IATSS Research* Vol. 36, No. 1: 20–23.
3) Calthorpe, Peter. 1993. *The Next American Metropolis: Ecology, Community, and the American Dream.* Princeton Architectural Press.
4) Transit Cooperative Research Program. 2004. *TCRP Report 102, Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects.* Transportation Research Board.
5) *Developing Around Transit: Strategies and Solutions That Work.* ULI (the Urban Land Institute). 2004.
6) Hayashi, Yoshitsugu, Kenji Doi, Hirokazu Kato, and International Association of Traffic and Safety Sciences, eds. 2009. *Toshi no kuoritei sutokku: Tochi riyo, ryokuchi, kotsu no togo senryaku* [Quality Stock of Cities: Integrated strategy of land use, green space and transportation]. Kajima Institute Publishing. (in Japanese)
7) “Special Supplement: Challenges and Visions for Implementing Light Rail Transit in Japan.” *IATSS Review* Vol. 34, No. 2. 2009. (in Japanese)
8) *Kotsu asesumento ni kansuru chosa hokoku sho* [Investigation Research Report on Transportation Assessment]. International Association of Traffic and Safety Sciences. March 2001. (in Japanese)
9) Seki, Tatsuya, and Akinori Morimoto. 2010. “Daikibokaihatsu ni okeru kotsu asesumento no seiri to kongo no tenbo” [A Review of Traffic Impact Assessment in Japan]. *Journal of JSCE(D)* Vol. 66, No. 2: 255–268. (in Japanese)

Recommended Reading

1) Randall, Thomas, ed. 2003. *Sustainable Urban Design: An Environmental Approach.* Spon Press.
2) Jenks, Mike, Elizabeth Burton, and Katie Williams, eds. 1996. *The Compact City: A Sustainable Urban Form?* Taylor & Francis.
3) *Site Impact Traffic Assessment: Problems and Solutions, Proceedings of the Conference, Chicago.* The American Society of Civil Engineering. 1992.
4) *Transportation Impact Analyses for Site Development.* Institute of Transportation Engineers. 2006.

Practical application projects for reference

A land utilization framework and transportation system for declining population: 132–135
Urban development from parking lots considering inner-city parking density: 140–143

Chapter 3
Transportation and the environment

3.1 Transportation and environmental issues

The 21st century has been called the "century of the environment," and the relationship between transportation and the environment has greatly changed due to changes in modes of transportation and the environmental issues being focused upon. For example, in "*Kotsu to Kankyo,*"[1] the Japanese translation of the 1988 OECD report "Transport and the Environment,"[2] issues such as air pollution and noise are raised as examples of the effects of land transportation on the environment, but there is no mention of global warming. The Framework Convention on Climate Change was only adopted at the 1992 Earth Summit in Rio de Janeiro, and was finally put into force in 1994. At that time, the Convention on Biological Diversity was hardly recognized, both in Japan and across the world.

In the Comparative Study on Urban Transport and the Environment (CUTE), sponsored by the Special Interest Group on Transport and Environment at the World Conference on Transport Research Society between 2001 and 2004, the focus of research was on environmental issues such as automobile emissions and noise, in particular localized air pollution and greenhouse gases.[3] This attests to the fact that, upon entering the 21st century, global warming was finally gaining widespread attention.

However, the environmental effects of transportation cover quite a wide range. The focus is most commonly placed upon automobile-related air pollution and global warming, as in the case in CUTE, to the extent that there is very little discussion regarding the relationship between the environment and other forms of transportation. Table 1 shows a listing of the environmental effects of major forms of transportation, and is based on the table in the above-mentioned OECD report,[2] with extensive additions and revisions by the author.

Regarding the effects on air pollution, automobiles are most commonly examined due to the scale of their effects, but marine and other water-based transportation, rail transportation, and air transportation also exhibit a variety of effects. For example, in 2011 air transportation accounted for only 3.9% of carbon emissions for the transportation sector as a whole, but the demand for international aviation services is expected to grow rapidly and reach a sixfold increase by 2050[4] compared to the demand in 2010. Before global warming took center stage, acid rain was a central topic, particularly in Europe. In recent

Table 1. The effects of transportation on the environment (Table 1 from reference 2, with additions by the author)

Transportation mode	Air	Land	Water (including groundwater)	Waste	Noise, vibration	Ecological impact	Landscape
Maritime transportation and inland waterways	CO_2 emissions Air pollution	Port facility construction Canal construction	Port facility construction Drilling and dredging rivers and coasts	Facilities, ship disposal	Noise around the port	Expansion of invasive species by ballast water Endocrine disruption of organisms by paint on ships	Loss of natural coast, rivers Landscapes with ships
Rail transportation	Carbon dioxide emissions Air pollution	Railway and station construction	Division of underground water veins by tunnel construction, etc.	Facilities and vehicle disposal	Noise and vibration near stations and along railways	Habitat fragmentation Collision accidents	Disruption of natural and traditional landscapes Creation of a new landscape resources (vehicles, bridges)
Road transportation	Carbon dioxide emissions Air pollution (In particular, fuel additives such as CO, HC, NOx, dust, and lead)	Construction of related facilities, including roads Terrain modification due to road construction Procurement of materials for road construction	Division of underground water veins by tunnels, etc. Development of water regions and changes in water system due to road construction Surface and groundwater contamination	Facilities and vehicle disposal, waste oil Battery disposal (especially for hybrid and electric vehicles)	Automobile noise and vibrations in cities and along major routes	Habitat fragmentation Collision accidents Disruption due to pollutants Contamination by anti-freeze agents Light pollution by streetlights	Disruption of natural and traditional landscapes Creation of new landscape resources (bridges, etc.)
Air transportation	Carbon dioxide emissions Air pollution	Airport facility construction	Development of water regions due to airport construction	Disposal of aircraft	Noise and shock waves near airports	Habitat destruction by airport development Collisions with airplanes (mainly birds)	Loss of natural landscapes Landscapes with airplane

years, however, fine particulate matter with particles of diameter 2.5 μm or less (PM 2.5) is the primary cause of pollution in China and other developing nations.

The impact of transportation on the environment can be roughly divided into the effects due to roads and other infrastructure, and the effects due to automobiles and other transportation vehicles. Transportation vehicles have greater impact in the atmosphere, but on the ground the primary impact is due to infrastructure maintenance. This is divided into facilities such as ports, stations, and airports, and the construction of linear routes such as canals, railways, and roads. Transportation routes must be continuous, and therefore necessarily separate natural environments and land use. Furthermore the scale of facilities such as airports is quite large, and this can have a significant impact on both natural environments and land use.

Transportation infrastructure is also the cause of much of the impact on water regions. The effects of transportation on rivers and coastal areas have been pointed out in many past studies, most of which show a degradation of water quality due to development. Disruption of underground water veins due to underground transportation via tunnels has also been shown to reduce and pollute underground water, and to increase maintenance costs for drainage of water. There are also many cases where transportation machinery leads to the pollution of water areas. Regarding ground transportation, the various chemical products emitted by automobiles are concentrated along roads, and then dispersed into the surrounding environment.

Large amounts of waste are produced when transportation-related infrastructure is abandoned or renewed, and when the vehicles that utilize such infrastructure exceed their serviceable lifetimes, these too must be treated as waste. In Japan, the Act for Automobile Recycling mandates that such vehicles be recycled, and recycling rates have reached approximately 99%.[5)] However, there is a possibility that the rapid spread of hybrid vehicles, and the expected increased popularity of electric automobiles and next-generation environmentally friendly vehicles, will result in increased battery disposal, so the cost of recycling may increase.

Regarding noise, with the exception of marine transportation, there has been extensive research, and a variety of measures have been attempted. Infrastructure maintenance exceeding a certain scale is subject to the Environmental Impact Assessment Law, and must meet certain legally determined standards. There has also been continued development for the suppression of noise and vibration due to transportation vehicles. Japan is currently developing a maglev train line and continues to expand Haneda Airport, so new issues related to noise and vibration are likely to develop.

There have been few investigations into the effects of transportation on organisms, despite various indications for doing so from the fields of biology and ecology. The largest impacts are habitat fragmentation and loss. As I explain in more detail below, the most frequently discussed measures are environmental mitigation and eco-roads. Various other effects are also seen, but two particular features of marine and other water-based transportation are extended distribution ranges of invasive species due to ballast water, and endocrine disruption due to the paint used on ships. In the case of air transportation, collisions between airplanes and birds are the major problem, which can also pose danger to human lives.

One final impact is that on landscapes. The OECD report[2)] makes no mention of this point. Nonetheless, transportation-related infrastructure has a significant impact both on natural scenery and on traditional and historic views that have been cultivated over many years.[6)] An interesting feature of this issue, however, is that transportation machinery and infrastructure itself can become a scenic resource. For example, one does not need a particular interest in railways to feel a sense of beauty when viewing a photograph of a train crossing over a bridge that straddles a valley, and there are many instances where transportation infrastructure itself becomes a popular landscape spot, such as in the cases of the Yokohama Bay Bridge or the Akashi Kaikyo Bridge.

3.2 Road greening and parkways

The environment and transportation infrastructure have developed in close association with each other. For example Hirasawa[7] describes how rows of trees were planted as far back as the early 7th century as a form of road greening in Japan, and how records from the 8th century state that the planting of these trees was mandated, as they provided traveling farmers with shade in which to rest and fruit to eat when they were hungry. The Tokugawa Shogunate later developed tree-lined roads throughout Japan, and the beginning of using stands of cherry trees for recreation was in the first half of the 18th century, when Tokugawa Yoshimune opened orchards in the area around Edo.[7] This can be viewed as the birth of Japanese-style open space planning.

The development of green space in the West received a major boost when Friedrich Franz Leopold III, the Lord of Dessau, became strongly influenced by the landscape gardens of England, and thereby renovated Wörlitz Castle into a landscape garden between 1768 and 1770. Landscaping was thereafter promoted throughout the territory, forming the birth of open space planning in Europe. It was the United States that first established a park system coupled with road planning.

The need for parks and green spaces was strongly felt as a result of the expansion of American cities in the early 19th century. New York's Central Park was designed by Frederick Law Olmsted in 1873. This was the first large-scale urban park to be built in the United States. At around the same time (1868) the first parkway—a road developed along with a park—was built in Brooklyn.[8] The definition of "parkway" remains unclear, and already has diverged from its original meaning, but later developments in Boston, Minneapolis, and Kansas City featured a variety of axial roadways combined with green spaces, also called parkways.[8] In late 19th-century Boston, the development of parkways and green spaces was sublimated into open space planning in the form of a park system.[9] This occurred before automobile usage was widespread, in a time where roads were generally used for horse-drawn carriages.

After automobile usage rapidly spread in the early 20th century, parkways appeared as roads designated for automobile use only. This was done to allow automobiles to travel at higher speeds than horse-drawn carriages, as exemplified by the development of the Long Rheinland State Parkway in the 1930s.[8] Parkways later began to spread throughout the world in various forms, such as national park roads and pay roads through scenic areas. American-style parkways were soon introduced into Japan, starting with the Shonan Coast Park Road (now part of National Highway Route 134), which began construction in 1931 and was completed in 1936, as the first parkway in Japan[10] (Fig. 1).

Figure 1. Current National Highway Route 134
(taken by the author in June 2014, near the Hamamiyama Kobanmae intersection)

3.3 Ecological mitigation and eco-roads

The development of railway and automotive technologies has realized high-speed movement, and automobiles in particular make possible high mobility that allows any-time, anywhere movement. The high-density development of supporting railways and roads has arisen alongside the development of high-speed ground transportation. Following World War II in particular, global political stability and economic development caused transportation infrastructure development to rapidly expand, and this began to have a large impact on the natural environment. In 1969 the United States enacted its National Environmental Policy Act and institutionalized various forms of environmental impact assessment in order to avoid, to the extent possible, the effects of various kinds of development on the natural environment. While falling far behind the countries of the West, in 1997 Japan too enacted its Environmental Impact Assessment Law. Development exceeding a certain scale is now required to undergo environmental assessment, the possible effects of business on natural environments are investigated, and furthermore follow-up surveys after project completion are also required. However, the institutionalization of mandatory environmental impact mitigation has gone even further in Western countries such as the United States and Germany. Environmental mitigation (often simply called “mitigation”) is a method for ensuring “no net loss” of wildlife habitats before and after development and other such activities through (1) avoiding effects by refraining from certain activities, (2) reducing effects by limiting certain activities, (3) correcting effects through repair, rehabilitation, and restoration, and (4) reducing or eliminating long-term negative effects through protection measures and management, supplying alternate resources, and making up for negative effects through replacement, with steps taken preferentially in that order.[11)] Figure 2 shows a railway near Frankfurt, Germany, in which quadruple tracks are being planned to meet the increased demands of recent years. Such artificially created railway embankments are a habitat for the sand lizard (*Lacerta agilis*), an endangered species in Germany, so this rail construction is likely to have a significant impact. Measures to develop alternative living spaces in the surrounding areas are therefore planned prior to construction so that the lizard populations can be maintained. The above-mentioned procedures for quantifying the total amount and quality of organism habitats are operated in the United States using a system called mitigation banking,[12)] which had begun to be utilized before the greenhouse gas emissions trading system was established.

Figure 2. Railway embankments are an important habitat for the endangered sand lizard (*Lacerta agilis*)
(taken by the author in July 2014, in Wetterau, Hessen, Germany)

Environmental mitigation is involved in all forms of development not just transportation infrastructure, but continuous linear developments such as roads and railways are characterized by the potential to divide organism habitats. This results in loss of habitat, as well as animal deaths due to vehicle collisions while trying to cross the road, disruption of life-cycles for amphibians and other animals that must travel between forests and waters, and reduced genetic diversity due to reduced chances for mating between adjacent populations. Therefore, there have been efforts toward reducing to the extent possible such effects on organisms, particularly with regard to animal movement, and such attempts are collectively referred to as "eco-roads." As in the case of environmental assessment, various cases have already been accumulated in the West and have begun to be introduced to Japan, starting with the 11th Five-year Road Development Plan, which called for the increased development of eco-roads.[13)] A wide variety of specific measures have been implemented, to protect not only fauna, but flora as well. The development of eco-roads is often positioned in the above-described environmental mitigation procedures in the West. Various cases have been seen in Japan too, but in most cases road construction is decided first, with tunnels and bridges for animals prescribed as symptomatic treatments, so in many cases it becomes questionable as to whether the effects are sufficient to allow calling such projects "eco-roads." A recent study[14)] indicated that somewhere between 89 and 340 million birds die in America each year due to collisions with automobiles, so further measures will likely be needed in the future.

3.4 Transportation and invasive species

I began by discussing global warming, but there is also a need to confront declines in biodiversity as a global environmental issue of the 21st century. Alongside the Framework Convention on Climate Change, the Earth Summit held in Rio de Janeiro in 1992 adopted the Convention on Biological Diversity, which entered into force in 1993. While previously having less recognition than global warming issues, the Convention on Biological Diversity's tenth meeting of the Conference of the Parties (also known as COP10) held in Aichi Prefecture in 2010 suddenly brought biological diversity to the spotlight in Japan. Japan's National Biodiversity Strategy[15)] gives detailed information regarding factors that threaten biodiversity, but another issue related to its relationship with transportation is the transfer of invasive species. One famous example is the white clover (*Trifolium repens*) commonly found in grasslands throughout Japan, having been brought here in the form of cushioning materials for packaging when trade between United States and Japan opened up. In manners such as this, when moving from place to place humans bring with them a variety of organisms, whether intentionally or not.

As an example characteristic of transportation, invasive species can be mixed in with the ballast water of ships. Seawater is held in ballast tanks to help stabilize ships, especially when they are traveling under light loads. This seawater will often contain many forms of aquatic life, and is released at a different port when the ships take on loads, and so can be carried quite a distance. Many aquatic organisms contained within can survive until release, especially considering the higher-speed vessels that have been developed in recent years. A well-known example of an invasive species attracting caution in Japan is the Mediterranean mussel (*Mytilus galloprovincialis*). Of course, there are also cases where native Japanese species are transferred to other locations. One such example is wakame seaweed (*Undaria pinnatifida*), which grew explosively in Australia, resulting in major damage to its fishing industry.

Increased demand for air travel has also promoted the migration of species, resulting in risks to humans. The most significant uninvited guests transported by aircraft are pathogens and viruses. Examples have been known ever since air travel became a common mode of transportation for tourists, but the risks associated with increased air travel finally gained wide recognition after 2000 due to severe acute respiratory syndrome (SARS) and the avian flu. Regarding the latter, the possibility of propagation overseas via wild birds had already been known, but the danger of the virus being transported by infected air passengers led to various areas worldwide measuring travelers' body temperatures using thermal sensors. Regarding SARS, an infected air passenger in 2003 lead to emergency measures being implemented in China and throughout the world. Another potential danger is illnesses such as West Nile fever which are transmitted not directly from person to person but through a vector that can also be carried on aircraft. Such dangers led to the Ministry of Health, Labour, and Welfare issuing a notice in 2003 titled "Measures against mosquitoes carrying West Nile fever arriving via aircraft from North America."

3.5 Toward a low-carbon transportation society

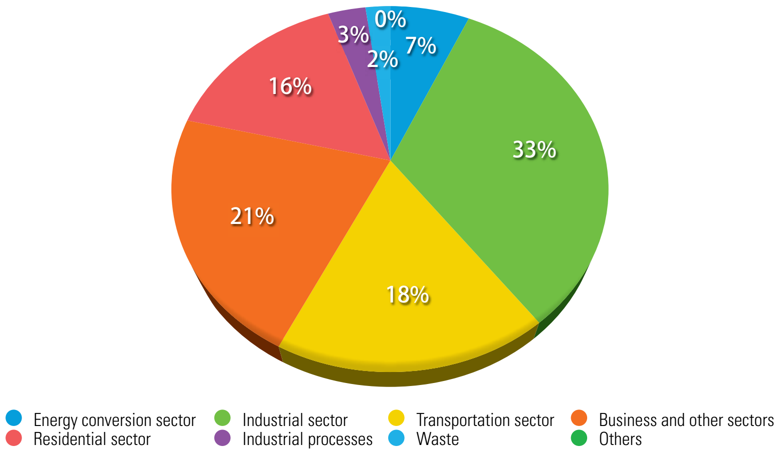


Figure 3. Carbon dioxide emissions (indirect emissions) by sector in Japan, 2012
(created by the author using data from the Greenhouse Gas Inventory Office, National Institute for Environmental Studies)

As mentioned earlier, global warming is generally recognized as the single most serious adverse effect of transportation. Figure 3 gives statistics for 2012, showing that the transportation sector makes up 18% of Japan's total carbon dioxide emissions, and this amount would certainly increase, were the manufacturer of transportation vehicles included as well. However, there has been a significant decrease of carbon emissions from the transportation sector since 2000. What was once a consistent upward trend has now become a major transformation.

Reducing carbon dioxide emissions from transportation requires three basic approaches. One is reducing emissions from vehicles. Another is improving transportation infrastructure. The last, which is much needed, is the construction of a transportation system that can help reduce emissions for society as a whole. This third type of system would include tax reforms and other measures.

Automotive manufacturers in particular are competing to develop and improve vehicles. Spurred in part by soaring fuel costs in Japan in recent years, consumers are increasingly aware of fuel economy. Hybrid vehicles with better fuel economy than purely gasoline-fueled automobiles accounted for 17% of new car sales in 2013. While next-generation automobiles continue to be developed, there has also been steady progress toward improving fuel efficiency and reducing carbon dioxide emissions for conventional internal combustion engines. Small cars that achieve 40 km/l fuel efficiency are expected to appear in 2015. The US and the EU have both set upcoming regulations on the amount of carbon dioxide that can be discharged by vehicles.

Carbon dioxide emissions can also be greatly reduced through transportation infrastructure improvements, for example by reducing congestion. In the Tokyo metropolitan area in particular, various measures have been taken to reduce chronic congestion, and carbon emissions have been reduced by constructing new bypasses and highways, among other methods. However, it is also possible that such improvements will result in increased traffic flow and thus increased travel distances, which will ultimately increase emissions. Recently there have been attempts at making real-time measurements of changes in traffic volumes over time, and optimizing traffic signal control according to traffic volumes. In addition, although they are scarce now, a recent movement has aimed to bring back roundabouts in various districts of Japan, given their proven carbon emissions–reducing effect.[16)]

Drastic reduction of carbon emissions will require a transformation of our transportation system. A variety of measures and technologies have been tested in European cities, including road pricing, car sharing, cycling road development, lowered public transportation fares, increased urban area parking fees, park-and-drive systems, and providing public transportation information via smartphones to promote the usage of public transportation rather than privately-owned vehicles. Vienna, Austria realized a 10-point increase in public transportation utilization between 1993 and 2012.[17)] Such efforts toward integration remain rare in Japan. However, Toyama City is frequently cited as a success story for moving toward becoming a more compact city design and for implementing light rail transit. The greening of taxation systems related to automobiles has also had a great effect on reducing carbon emissions. Western countries have undertaken tax reform that meticulously considers the environment in relation to the realities of the region.[18)] Japan too has implemented tax incentives for environmentally friendly vehicles, and from October 2012 has introduced tax measures related to global warming that add to existing taxes on petroleum and coal products. The tax rate will be raised in stages through April 2016. Leveraging revenues from taxes levied as measures against global warming issues will allow for ongoing implementation of energy source CO_2 emission reduction, for example through reduced energy usage measures, the proliferation of renewable energy, and the greening and increased efficiency of fossil fuels.

References

1) Japan Economic Research Institute, trans. 1993. "Kotsu to kankyo" [Transport and the environment]. *Research Report* Vol. 92, No. 13: 1–212. (in Japanese)
2) Organisation for Economic Co-operation for Development. 1988. *Transport and the environment*.
3) Nakamura, Hideo, Yoshitsugu Hayashi, and Kazuaki Miyamoto, trans. 2004. *Toshi kotsu to kankyo: Kadai to seisaku* [Urban Transport and the Environment: An International Perspective]. Institution for Transport Policy Studies. (in Japanese)
4) International Civil Aviation Organization. 2013. *Environmental report: aviation and climate change*.
5) Japan Automobile Recycling Promotion Center. 2014. "Automobile Recycling Law." Accessed June 5, 2014. http://www.jarc.or.jp/automobile/manage/.

6) European Environment Agency. 2011. *Landscape fragmentation in Europe: Joint EEA-FOEN report*. Copenhagen: Publications office of the European Union.
7) Hirasawa, Tsuyoshi. 1996. "The origin and development of a row of trees before modern times in Japan." *IATSS Review* Vol. 22, No. 1: 4–12. (in Japanese)
8) Ishikawa, Mikiko. 1993. "A historical study on the establishment of parkways in U.S.A." *J-STAGE* Vol. 13: 105–120. (in Japanese)
9) Ishikawa, Mikiko. 2001. *Toshi to ryokuchi* [Cities and Green Spaces]. Iwanami Shoten. (in Japanese)
10) Koshizawa, Akira. 1996. "Evolution of boulevard and street trees in urban planning." *IATSS Review* Vol. 22, No. 1: 13–23. (in Japanese)
11) Morimoto, Yukihiro, and Akira Kameyama, eds. 2001. *Miteigeshon: Shizen kankyo no hozen/fukugen gijutsu* [Mitigation: Conservation of natural environments and restoration technologies]. Soft Science. (in Japanese)
12) Tanaka, Akira. 2010. "Wetlands conservation by mitigation banking: Current status of economic mechanism for biodiversity offsets: Biodiversity banking in U.S.A." *Journal of Japan Society on Water Environment* Vol. 33, No. 2: 54–57. (in Japanese)
13) Overseas Eco-roads case investigation group, ed. 1999. *Eko rodo bukku: Ikimono to kyousei suru doro zukuri kaigai jire shu* [Eco-roads book: A collection of cases from overseas on road construction that promotes coexistence with living things]. Japan Highway Landscape Association. (in Japanese)
14) Loss, Scott. R., Tom Will, and Peter P. Marra. 2014. "Estimation of bird-vehicle collision mortality on U.S. roads." *The Journal of Wildlife Management*. Vol. 78, No. 5: 763–771. http://doi.org/10.1002/jwmg.721.
15) Nature Conservation Bureau, Ministry of the Environment, Government of Japan. 2012. *Living in harmony with nature: National biodiversity strategy of Japan*.
16) Matsuda, Shoji, Hiroshi Sukigara, and Shigeo Mori. 2014. "Implementation of a roundabout initiative in Iida city." *IATSS Review* Vol. 39, No. 1: 15–21. (in Japanese)
17) Wiener Stadtwerke. 2014. "Modal Split." Accessed June 5, 2014. http://www.nachhaltigkeit.wienerstadtwerke.at/daseinsvorsorge/oepnv/modal-split.html.
18) Imanishi, Yoshikazu, and Masayuki Shibahara. 2014. "Motor vehicle-related tax systems in the U.S. and Europe." *IATSS Review* Vol. 38, No. 3: 182–190. (in Japanese)

Recommended Reading

1) World Conference on Transport Research Society & Institute for Transport Policy Studies. 2004. *Urban Transport and the Environment: An International Perspective*. Emerald Group Publishing Limited.
2) Benedict, Mark A., and Edward T. McMahon. 2006. *Green Infrastructure: linking landscape and communities*. Washington, DC: Island Press.

Practical application projects for reference

A land utilization framework and transportation system for declining population: 132–135

Chapter 4 Traffic engineering

Traffic engineering got its start with the popularization of internal combustion vehicles in the early 20th century, and has developed along with the progress of global motorization that began after World War II. Traffic engineering traditionally encompasses scientific and technical fields related to reduction of the negative aspects of automobiles, such as traffic congestion, traffic safety, and pollution (environmental load). This chapter introduces traffic flow sciences and provides an overview of related technologies.

4.1 Traffic flow fundamentals

The three variables, namely, traffic volume, density, and speed, are fundamental to understand automobile traffic flow on roads.

The term *traffic flow rate* [vehicles per hour (veh/h)]—or the term *traffic volume* in general—describes the number of vehicles passing through a given location per unit time based on the measurement conducted over a duration of 1 h or possibly less. Traffic flow is simply the number of automobiles passing through a given point, and thus is the *traffic demand* at the location when there is no traffic congestion. On the other hand, if there is traffic congestion, the traffic volume is equal to the *traffic capacity* of the downstream bottleneck (see Section 4.2) that causes the traffic congestion.

The term *traffic density* [veh/km] describes the number of vehicles present at a given time per unit space length based on measurement conducted over an interval of 1 km or possibly shorter. Unlike traffic volume, direct measurement of traffic density requires simultaneous aerial observation over relatively long stretches of road and is not very easy.

Traffic speed [km/h] is the representative speed of a traffic flow comprising various vehicles traveling at different speeds. This representative value must be the *space mean speed* of individual vehicles. It is calculated by dividing a given space length by the mean of travel times required for individual vehicles to travel the length. The space mean speed can be estimated by the harmonic mean of the speed of each vehicle observed at a given location. Using the space mean speed as the traffic speed, Eq. (1) holds.

$$(\text{Traffic volume } Q) = (\text{Traffic density } K) \times (\text{Traffic speed } V) \quad (1)$$

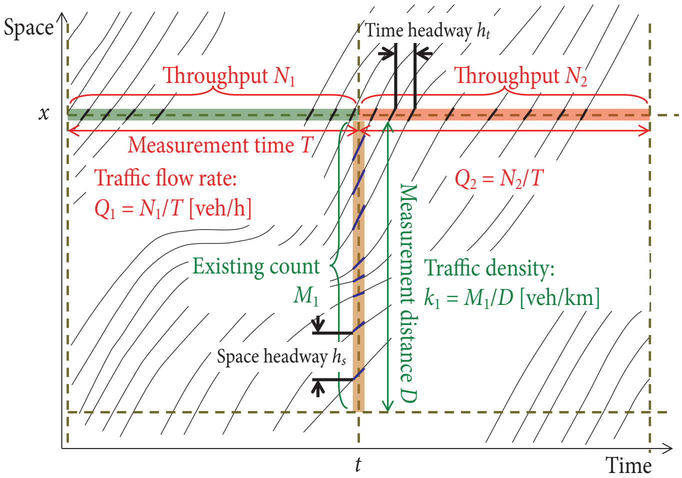


Figure 1. Time–space diagram

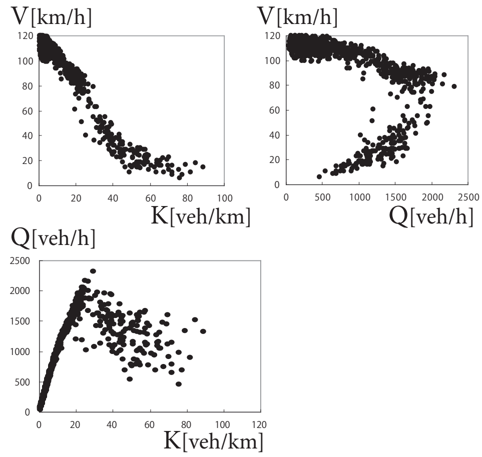


Figure 2. Example measurement of the relation between traffic volume, density, and speed

This equation does not generally hold when the simple arithmetic mean is used as the representative speed of traffic flow. Indeed, Eq. (1) corresponds to the law of conservation of mass in basic physics, which is universally holds for general flow phenomena, not only traffic flows.

Figure 1 shows time–space trajectories of individual vehicles as well as the relation between traffic volume and density. As the figure shows, these two variables are in a symmetric relation on the time and space axes, with the reciprocal of the *mean time headway* corresponding to the traffic volume, and the reciprocal of the *mean space headway* corresponding to the traffic density.

Figure 2 shows the mutual relations among the three variables, using actual vehicle detector measurements aggregated in every 5 min and the calculated traffic density obtained by Eq. (1) using the measured traffic volume and speed. In general, the speed approaches a maximum value (the *free speed*) as traffic density approaches zero, and traffic density approaches a maximum value (the *saturation density*) as speed approaches zero. These two variables are in a monotonically decreasing relation. Furthermore, there exists a maximum traffic volume reached at a certain value of traffic density (the *critical density*) and a certain value of speed (the *critical speed*). Densities above the critical density and speeds below the critical speed indicate a state of *traffic congestion*; conversely, densities below the critical density and speeds above the critical speed indicate an uncongested traffic state.

Using the monotonic decreasing relationship between density and speed combined with Eq. (1), it is straightforward to show that the traffic volume–density (volume–speed) relationship is a binary function that has a maximum value of traffic volume. This is the theoretic basis for the existence of a maximum traffic volume (*capacity*) for road traffic.

4.2 Features of traffic congestion

4.2.1 Bottlenecks and the definition of traffic congestion

Traffic congestion is defined as a traffic state (a *waiting queue*) in which queued traffic (*congested vehicles*) develops upstream from a traffic capacity bottleneck that occurs when traffic demand exceeding the bottleneck traffic capacity attempts to enter the bottleneck. A bottleneck is a road section in which traffic capacity is relatively low in comparison with upstream and downstream road segments. Traffic congestion on inter-city expressways in Japan is generally triggered at sag sections (road sections with longitudinal slope changes from downward to upward) or at tunnel entrances.[1] On the other hand, major bottlenecks on European or American expressways are merging or diverging sections and weaving sections. Major bottlenecks on surface streets are key signalized intersections with heavy traffic, queues forming at parking garages of large shopping centers, and on-street parked cars. From the definition of traffic congestion, it is obvious that there is no fixed speed threshold to distinguish congested traffic conditions from uncongested traffic conditions. For simplicity, 40 km/h on inter-city expressways and 20 km/h on urban expressways are used as the thresholds to identify traffic congestion for practical use in Japan.

4.2.2 Calculating traffic congestion

Figure 3 shows a simplified assumption of the volume–density relationship per lane based on the data shown in Fig. 2. Figure 4 schematically shows the change in traffic congestion caused by a bottleneck on a time–space diagram. Point a (traffic volume A, traffic density k_1, velocity v) in Fig. 3 represents the traffic conditions of traffic demand A attempting to pass through a bottleneck with capacity C_b (location BN in Fig. 4). Here, in the case where $A > C_b$, traffic congestion occurs upstream of the bottleneck (point b in Fig. 3; traffic volume C_b, traffic density k_2, velocity v_b), and the tail of the congestion queue moves upstream. The shock wave speed u_{ab} is given by the following Eq. (2) according to shock wave theory:[2)]

$$u_{ab} = (A - C_b) / (k_1 - k_2) \tag{2}$$

The shock wave speed u_{ab} is the slope of the line connecting a and b in Fig. 3. The slope in Fig. 3 is obviously negative, which indicates that the shock wave moves upstream. The boundary between demand traffic condition a and traffic congestion b moves at speed u_{ab} in Fig. 4. If the traffic demand changes to point c in Fig. 3 (traffic volume A', traffic density k_3, velocity v) and $A' < C_b$ holds at time T_1, then u_{cb} is positive, meaning that the tail of the congestion queue shortens until it vanishes at time T_2.

For example, when traffic demand A=1800 veh/h arrives at a bottleneck with capacity C_b=1600

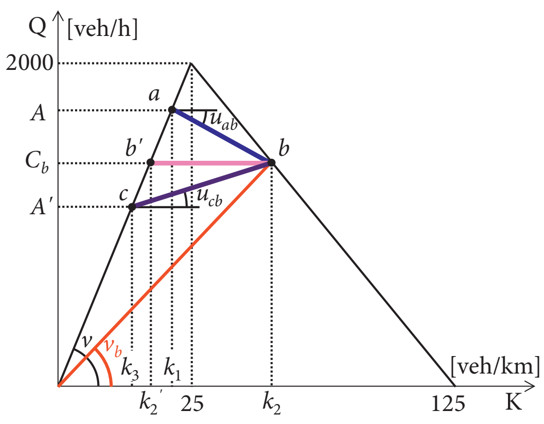


Figure 3. A model of traffic volume–density relation

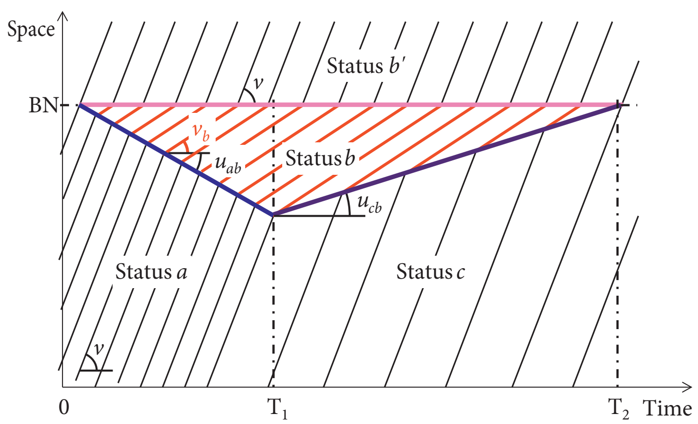


Figure 4. Expansion and reduction shock wave of traffic congestion

veh/h, the tail of traffic congestion moves upstream at a speed of u_{ab} = (1800−1600) / (22.5−50) ≈ −7 km/h, so if T_1 = 2 h, the traffic congestion length L ≈ 14 km. If the traffic demand decreases to A' = 1500 veh/h at time T_1, then u_{cb} = (1500−1600) / (18.75−50) = 3.2 km/h and time T_2 is $T_1 + L/u_{cb}$ ≈ 6.5 h.

It is generally known that the excess of traffic demand over the bottleneck capacity is at most approximately 12–15% (in the case of this example, it is 12.5%, as given by 1800/1600 = 1.125) even when traffic congestion occurs due to an increase in traffic demand. It is also known that the duration of traffic congestion (6.5 h in this case) greatly exceeds the duration of traffic demand exceeding the capacity (2 h).[3)]

4.2.3 Features of traffic congestion on ordinary expressway sections

It was recently found that on inter-city expressways in Japan, bottlenecks at sag and tunnel entrance sections together account for 80% of all bottleneck sections.[4)] There is no merging or traffic signals at such sections, but slight speed perturbations due to slight changes in slope cause speed reduction shock waves that propagate upstream, causing traffic congestion. The level of traffic demand causing such phenomena varies widely in the range of 75–90% of the normal capacity for ordinary expressway sections. This variation is thought to be due to the differences between individual drivers and between vehicle types in car-following behavior.[5)]

Furthermore, once traffic becomes to traffic congestion, the bottleneck capacity declines further, to around 60% of the normal capacity for ordinary expressway sections. This is because drivers' car-following behavior becomes sluggish due to driver boredom and fatigue caused by the low speed in traffic congestion.[5)] Assume traffic demand is 1800 veh/h per lane as shown in Fig. 3, and the reduced bottleneck capacity is 1600 veh/h per lane, which is equivalent to 80% of an ordinary expressway section's normal capacity of 2000 veh/h per lane. The speed of extension of the traffic congestion tail is calculated to be approximately 7 km/h (see Section 4.2.2). If the reduced traffic capacity after formation of traffic congestion is 1200 veh/h per lane, which is equivalent to 60% of the normal capacity of an ordinary expressway section, the speed of extension of the traffic congestion tail doubles, to approximately 14 km/h based on Fig. 3 and Eq. (2). At a sag section, the traffic capacity is further lowered after formation of traffic congestion, and causes a rapid increase in the length of the traffic congestion queue. Furthermore, even when the traffic demand is reduced, the duration of traffic congestion is prolonged because the traffic congestion queue shortens at a lower speed. These are the reasons why congestion on expressways easily grows and persists.

4.3 Traffic performance-oriented planning and design of road networks

Expressways are the main arteries for high-volume, high-speed automobile transportation. They include long-distance nationwide expressways that form the backbone of the national transportation network, expressways that constitute major networks within regional areas, and urban expressways within large cities. For surface roads accepting more variety of transportation modes including pedestrians and cyclists, there are different functional classifications according to connectivity scale. Roads in cities furthermore perform various non-transportation functions, such as providing space for infrastructure like sewage and gas lines and performing disaster prevention functions to prevent the spread of fire. This makes such roads within cities (streets and avenues) quite different from inter-city roads (expressways and highways). In recent research activities in Japan, focus has been placed on such difference in transportation functions in hierarchical road classifications the concept of "performance-oriented" road planning and design has been promoted with the goal of attaining a road network that provides a certain level of traffic service functionality.[6)]

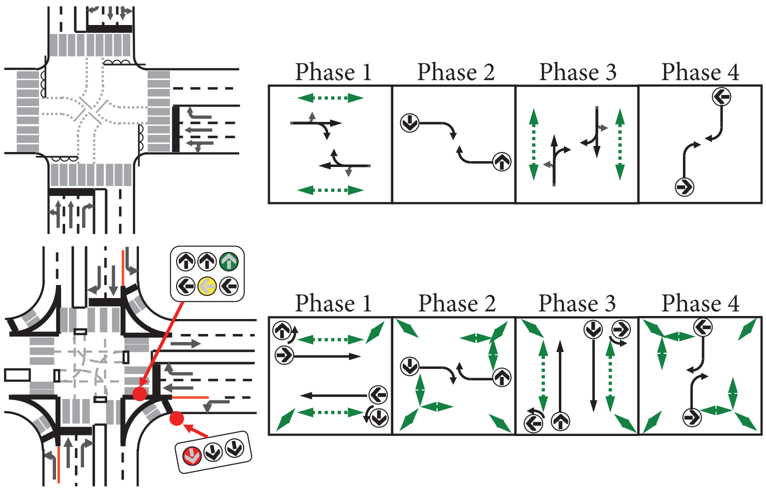


Figure 5. Example of traffic control improvement at a key signalized intersection

Junctions, the crossing points of roads, are key locations for transportation and are one of the most important elements for ensuring hierarchical road functionality. Many traffic capacity bottlenecks are at junctions, especially at key signalized at-grade intersections of surface streets. At intersections where traffic demand is concentrated, there are needs for proper geometric design (a sufficient number of lanes, grade separation, traffic islands, etc.) and for traffic signal phasing plan and optimization of signal control parameters (cycle, green split, and offset) to prevent the occurrence of traffic congestion (Fig. 5).

There are many intersections where the capacity (C_b) is high enough so that they are free from traffic congestion and capacity bottleneck. Even when the traffic demand D is extremely low (0 to $D \ll C_b$), waiting time (delay) occurs at signalized intersections corresponding to the signal control parameters. On the other hand, when traffic demand exceeds a certain volume ($D > Q_0$) at an unsignalized intersection, the delay under unsignalized control may exceed that under signalized control. For intersections with moderate demand ($0 \ll D$ to $Q_0 < C_b$), roundabouts have attracted attention in recent years in Japan as a method for both reducing delay and greatly reducing the risk of rear-end collisions and *deai-gashira* collisions (collisions that occur when vehicles, bicycles, pedestrians, etc. suddenly enter into an intersection) frequently observed at unsignalized intersections. There has been increasing momentum for the introduction of roundabouts in Japan.

To ensure a certain level of transportation functionality for arterial roads, it is important that traffic flow on arterial roads not be inhibited much at minor intersections. Effective means to that end include techniques concerning road geometric design and traffic operation and control, such as not connecting minor streets to arterial roads, limiting the allowance of traffic entering/exiting arterial roads by left turns only, and providing a dedicated auxiliary right turn lane (or pocket) at the median of arterial roads to separate this exiting right turn traffic from the main traffic stream on the road. The concepts described above are called "access management" in the United States[7)] which aims to establish a systematic scheme.

4.4 Road traffic management-based countermeasures

4.4.1 Fundamental ideas

The basic concepts of countermeasures for traffic congestion reduction or elimination are adjusting traffic demand and increasing bottleneck capacity. The former includes well-known traffic demand management (TDM), as well as additional efforts toward more dynamic adjustment methods in recent years such as providing traffic information and route guidance. The latter mainly includes physical measures such as increasing the number of lanes and expanding road networks, and additionally entails the introduction of active traffic management (ATM), which has been popular in Europe in recent years (see Section 4.4.2).

Improving traffic safety requires a more multifaceted approach that includes not only traffic engineering, but also vehicle technologies and the elucidation of human factors. Traffic congestion, particularly on expressways, is a significant cause of rear-end and near collisions of vehicles, and therefore, traffic congestion alleviation measures may also significantly reduce such accidents.[8)] It is important to let drivers naturally understand the road geometric structure and conditions by applying proper road alignment, arrangement planning of intersections, and so forth. Appropriate setting of overall traffic restrictions, including signal control planning, may also result in highly safe spaces for expressways, as well as for surface streets which are shared with pedestrians and cyclists.

Environmental impacts due to road vehicular traffic include noise, air pollution, and greenhouse gas emissions. Improvements in automobile performance and fuel quality have resulted in significant lessening of noise and air pollution problems in Japan in recent years, and improved fuel economy has reduced carbon dioxide emissions. Nonetheless, traffic congestion and repeated stopping and starting caused by traffic signals would lead to needless carbon dioxide emissions,[9)] and therefore any traffic smoothing policies to alleviate traffic congestion or to reduce number of stops are effective at reducing the environmental impact of road vehicular traffic.

4.4.2 Expressway traffic measures

Expressways are motorways (dedicated roads for automobiles) that serve as the main arteries for high-volume, high-speed nationwide and urban transportation. Frequent traffic congestion on expressways is a functional failure of these arteries, and leads to major losses to the country and to regional communities. Reducing congestion, especially on expressways, is thus extremely important. Ramp metering, which controls traffic volume at on-ramps, has become a common measure, and ATM such as lane-based variable speed limits (Fig. 6) and temporary hard shoulder opening has also been popular in developed countries except Japan.

Particularly severe traffic congestion was expected to be caused by partial opening of the Shizuoka segment of the New Tomei Expressway due to traffic concentration on the Tomei Expressway section between the Otowa-Gamagori Interchange and Toyota Junction prior to opening the Aichi segment. Therefore, a policy was implemented that increased the number of traffic lanes on the Tomei Expressway by narrowing them as shown in Fig. 7, while keeping road width unchanged.[10) This measure in Japan resulted in a great reduction of traffic congestion and traffic accidents on the Tomei Expressway section. An advanced automotive technology that has recently been attracting attention is adaptive cruise control (an advanced form of cruise control, which automatically maintains a constant speed). Adaptive cruise control adjusts the vehicle's speed and spacing ahead to conform to the leading vehicle's behavior. Because drivers' car-following behavior is a prime cause of bottlenecks on ordinary expressway sections (see Section 4.2.3), adaptive cruise control technology is expected to help reduce traffic congestion.[11)]

Figure 6. Example of lane-based variable speed limits (U.K.)


Figure 7. Increase to three lanes between the Otowa-Gamagori Interchange and the Toyota Junction on the Tomei Expressway (source: NEXCO Central Nippon Expressway Co., Ltd. press release)

4.5 Future trends in traffic management

One issue in traffic engineering is the extreme difficulty of running laboratory experiments. This makes careful practical observations and investigations in the field important. Small differences and changes in traffic flow, such as 10–20% variations in traffic demand and the emergence of traffic congestion at sag sections due to individual differences in driver behavior, can have a significant impact on the characteristics of traffic flow: whether it is congested or uncongested. The conventional point observations with vehicle detectors described in Section 4.1 have limitations to describe such temporal and spatial variations.

Advanced information technology has enabled the establishment of "probe" technology that allows temporally and spatially continuous measurement and monitoring of traffic status via automobile-mounted navigation systems or drivers' smartphones. Complete knowledge of the overall quantitative features of traffic flow, however, remains difficult because such techniques provide only sampled data.

An estimation method of the overall traffic state in combination with data from vehicle detectors and probe data has recently been developed by applying the traffic flow theory described in Section 4.2.[12] It is expected that the accumulation of large amounts of detector and probe data and the application of recent data mining technologies will provide dramatic increases in our knowledge of overall traffic states. Based on knowledge derived from such accumulated data, real-time use of sensor and probe data will allow the establishment of "nowcast" technology[13] to estimate the current traffic state through the application of theory-based traffic simulation models. The dynamic flexible application of nowcast technology applied to traffic information provision, route guidance systems, and ramp metering and TDM measures should result in minimization of daily recurrent traffic congestion. The nowcast technology is also considered to allow for prompt planning and execution of countermeasures against bad weather, large events, traffic accidents, and other incidents that are difficult to predict.

For example, Fig. 8 shows the state of extraordinarily massive traffic congestion that occurred on major arterial roads in the Tokyo Metropolitan Area immediately after the Great East Japan Earthquake on March 11, 2011.[14] Gridlock, which is the phenomenon where an entire road traffic network becomes paralyzed, emerged on that day. Gridlock can be defined as the traffic state where the throughput of a bottleneck is reduced to a value lower than the original bottleneck capacity by the tail of a traffic congestion formed upstream of the bottleneck extending to the bottleneck location on a loop-shaped road network. Gridlock is a serious traffic congestion phenomenon that is extremely difficult to resolve once it starts. It is believed that the development of a system for real-time detection of gridlock, or the establishment of traffic control methods for predicting and avoiding it, would be a significant contribution leading to increased stability and reliability of road transportation systems.

Figure 8. Gridlock of arterial roads in Tokyo

References

1) Koshi, M. 1985. "Traffic Flow Phenomena in Expressway Tunnels." *IATSS Research* Vol. 9: 50–56.
2) Lighthill, M. J., G. B. Whitham. 1955. "On Kinematic Waves: 2. A Theory of Traffic Flow on Long Crowded Roads." *Proceedings of the Royal Society of London A* Vol. 229: 317–345.
3) Koshi, M., H. Akahane, and M. Kuwahara. 1989. "Explanation of and Countermeasures against Traffic Congestion." *IATSS Research* Vol. 13, No. 2: 53–63.
4) http://www.mlit.go.jp/road/ir/ir-council/autopilot/pdf/05/6.pdf.
5) Koshi, M., M. Kuwahara, and H. Akahane. 1992. "Capacity of Sags and Tunnels on Japanese Motorways." *ITE Journal* Vol. 62, No. 5: 17–22.
6) Oguchi, T. 2008. "Redesign of Transport Systems on Highways, Streets and Avenues." *IATSS Research* Vol. 32, No. 1: 6–13.

7) Transportation Research Board. 2003. *Access Management Manual*.
8) Oguchi T., H. Akahane and Y. Yamada. 2004. "Analysis of Accident Rate in Critical Condition of Traffic Flow on Expressways." *Traffic Engineering* Vol.39, No.3: 41-46. (in Japanese)
9) Oguchi T. and M. Katakura. 2000. "New Conceptual Evaluation Method of Amount of Exhaust Emission Gas on Vehicular Road Traffic." *Advances in Transport (Urban Transport VI)* Vol.6: 383-392.
10) http://media2.c-nexco.co.jp/images/press_conference/78/2918114934ea7888494e01.pdf
11) Kanazawa, F., K. Suzuki, K. Sakai, and K. Iwatate. 2013. "Conducting the FOT to Evaluate the Driving Practice for Smooth Traffic to Mitigate Traffic Congestion at Sag Sections on Expressways. " In *Proceedings of 20th World Congress on ITS*. CD-ROM.
12) Mehran, B., M. Kuwahara, and F. Naznin. 2012. "Implementing Kinematic Wave Theory to Reconstruct Vehicle Trajectories from Fixed and Probe Sensor Data." *Transportation Research Part C* Vol. 20: 144–163.
13) Hanabusa, H., M. Kobayashi, K. Koide, R. Horiguchi, and T. Oguchi. 2013. "Development of the Nowcast Traffic Simulation System for Road Traffic in Urban Area." In *Proceedings of 20th World Congress on ITS*. CD-ROM.
14) Oguchi, T., M. Ito, R. Mizuta, R. Horiguchi and M. Iijima. 2013. "Analysis with Traffic Simulation and Evaluation of Traffic Congestion Mitigation Measures for the Tokyo 23-wards at a Great Earthquake Disaster. " *Proceedings of Traffic Engineering Meeting*, Vol. 33: 273-278. (in Japanese)

Recommended Reading

1) May, A. D. 1990. *Traffic Flow Fundamentals*. Prentice Hall.
2) Daganzo, C. F. 1997. *Fundamentals of Transportation and Traffic Operations*. Elsevier Science.

Practical application projects for reference

Practical optimal signal control emphasizing pedestrian road crossing realities: 144–147
Significant reduction of cycle length via a two-stage crossing system: 148–151
A study on the practical deployment and promotion of safe and ecological roundabouts: 152–155
A study on the role and limitations of motorcycles as a means of urban transport in Southeast Asia: 156–159

Chapter 5

Intelligent Transport Systems

5.1 An introduction to ITS

5.1.1 What is ITS?

The term ITS was coined in 1994, and stands for "Intelligent Transport Systems" or "Intelligent Transportation Systems." In a broad sense, an ITS is a system relating to mobility that has increased in sophistication through information technology (IT). However, the specific terms and concepts differ according to the country and situation.

The Japanese government and the specified nonprofit corporation, ITS Japan, use "*kodo doro kotsu shisutemu*," meaning "intelligent road and transportation systems," but the Institute of Electronics, Information and Communication Engineers, the Information Processing Society of Japan, the Institute of Electrical Engineers of Japan, and others use "*kodo kotsu shisutemu*," which in English means "intelligent transport systems."

As Fig. 1 shows, The Ministry of Land, Infrastructure, Transport and Tourism defines an ITS as "a new transport system constructed with the goal of alleviating road traffic problems such as accidents and congestion using state-of-the-art information and communication technologies to create an information network based on people, automobiles, and roads."[1)]

ITS Japan explains the concept as, "a system for solving a variety of problems that road traffic faces, such as accidents, congestion, and environmental measures, through the exchange of information between people, automobiles, and roads. It attempts to coexist with the environment and improve energy efficiency by eliminating accidents and congestion while at the same time optimizing the road network by utilizing state-of-the-art information and communication and control technologies. In addition, it has the potential to create new industries and markets with its diverse related technologies, and promises to be a driving force in changing the social system."[2)]

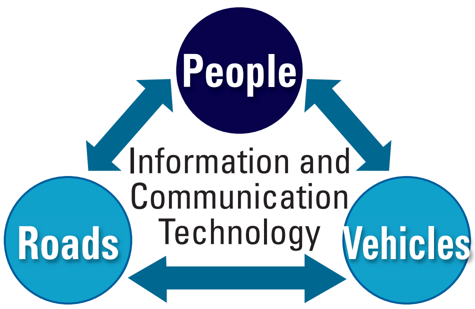


Figure 1. The Ministry of Land, Infrastructure, Transport and Tourism's ITS[1)]

In each academic society listed above, ITS are not limited to automobiles, but also include railways, aircraft, and shipping traffic as areas that can also benefit from the sophistication of mobile IT. This mobility-oriented concept is popular in other countries, especially in Europe.

5.1.2 Organizations promoting ITS

In a variety of countries, ITS are promoted by a wide range of organizations including governments, local governments, industries, and academic societies. For example, as of 1996 the ministries and agencies promoting ITS in Japan were called the "five concerned ministries," consisting of the National Police Agency, Ministry of International Trade and Industry, Ministry of Transport, Ministry of Posts and Telecommunications, and Ministry of Construction. After subsequent reorganization and renaming, there are currently many more ministries and agencies involved, including the Cabinet Secretariat, Cabinet Office, National Police Agency, Ministry of Internal Affairs and Communications, Ministry of Economy, Trade and Industry, and Ministry of Land, Infrastructure, Transport and Tourism. Also, ITS Japan, a specified nonprofit corporation, has been essential in the promotion of ITS in Japan. ITS Japan has taken the role of Secretariat of the ITS World Congress and ITS Symposium, and is responsible for the publication of academic journals such as the *International Journal of ITS Research*. It actively promotes ITS activities in the spirit of international cooperation among industry, government, and academia.

The ITS World Congress, described later, is a trilateral symposium held every year, rotating between Europe, Asia, and the United States, and centering around the European Road Transport Telematics Implementation Coordination Organization, which is a private-public organization for promoting ITS in Europe, the Intelligent Transportation Society of America, which is a nonprofit scientific and educational organization for the purpose of ITS promotion and serves as the official advisory committee of the US Federal Department of Transportation, and ITS Japan. Moreover, there are many other private–public organizations promoting ITS in each country and together with the efforts of a variety of universities and research institutes, ITS are receiving broad promotion.

In addition to the IEEE and Transportation Research Board in the United States and the three Japanese academic societies mentioned above, other academic societies, such as the Society of Automotive Engineers of Japan, the Japan Society of Civil Engineers, the Japan Society of Traffic Engineers, and the International Association of Traffic and Safety Sciences, are also involved in the promotion of ITS. ISO/TC 204 - Intelligent Transport Systems plays a central role in standardization, but coordination with International Telecommunication Union is still undertaken, especially in the field of information and communication.

5.1.3 Aims of ITS

According to the definition of ITS, the range and concept used in each field may change, but the purpose of ITS generally relates to the "safety, efficiency, environmental concerns, and convenience of traffic and transport via the thorough utilization of IT." Therefore, changes in information and communication, positioning, and underlying sensing technology by means of lifestyle and value changes as well as the advancement and dissemination of science and technology, always bring about changes in the ITS world.

The next section will review the history of ITS.

5.2 History of ITS

5.2.1 The beginning of the ITS World Congress and the transition of Japan's ITS

The annual World Congress on Intelligent Transport Systems (hereinafter, World Congress) was first held in Paris in 1994, and the following year saw it held in Yokohama. The first World Congress was named and positioned as "The First World Congress on Advanced Transport Telematics and Intelligent Vehicle-Highway Systems," and the theme was "Towards an Intelligent Highway Transport System."[3)] The name was officially changed to contain ITS at the second World Congress. Japan enthusiastically embraced ITS following the Congress in Yokohama in 1995, and in 1996 the "Grand Plan to Promote Intelligent Transport Systems (ITS)" was established by five concerned (then-) ministries and ITS has been actively promoted ever since. Figure 2 shows the subsequent timeline.

The period from 1996 until mid-2004 came to be known as the first stage of ITS. As of 2014, 21 services in 9 fields have been launched, such as the widely used Vehicle Information and Communication System (VICS), which is representative of a sophisticated navigation system, and Electronic Toll Collection (ETC).[4)]

An ITS is one system made of many, and understanding of the underlying systems is important to understand the system as a whole. Many of these were small-scale systems created as dedicated systems for their various uses (system by system). Recently, systems tend to be applications or "apps" built on

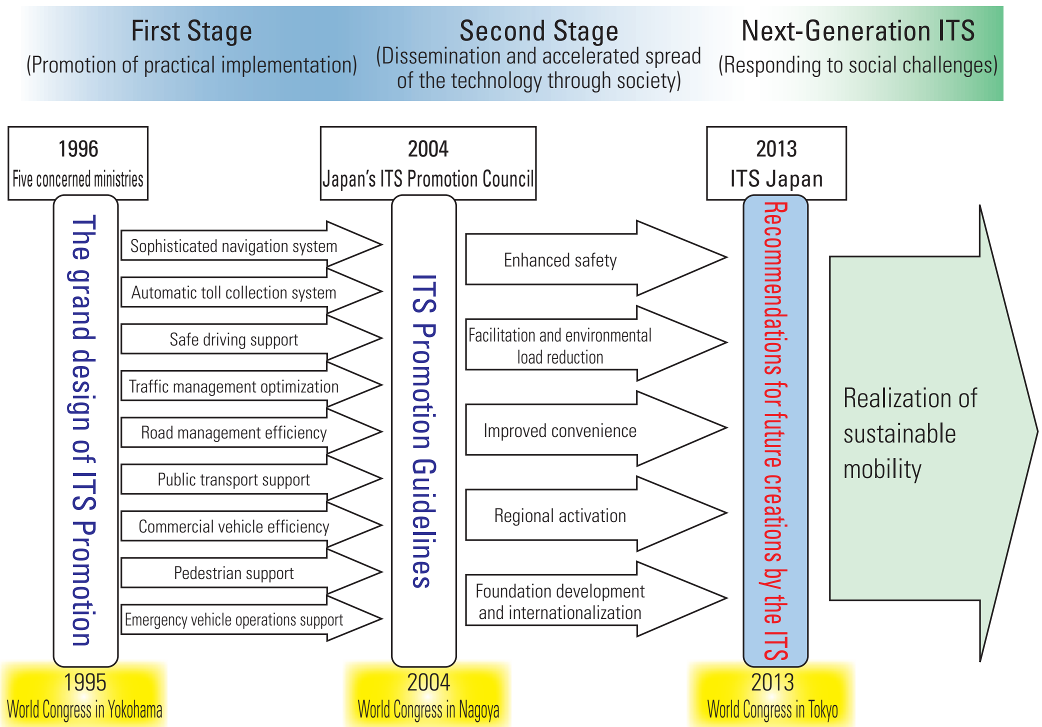


Figure 2. The flow of Japan's ITS[4)]

platforms. For example, the creation of a word processing application running on top of an OS platform on a home computer, which led to the disappearance of the word processor as a dedicated machine, or the increased rate of smartphone use after the development of apps that could run on mobile platforms such as Android or iOS, which ushered in a decline in the use of standard portable handsets or feature phones. Such a shift has also seen dedicated car navigation systems making the changeover to car navigation apps running on smartphones. In short, the shift from dedicated systems to platform oriented systems is a significant change (Fig. 3).

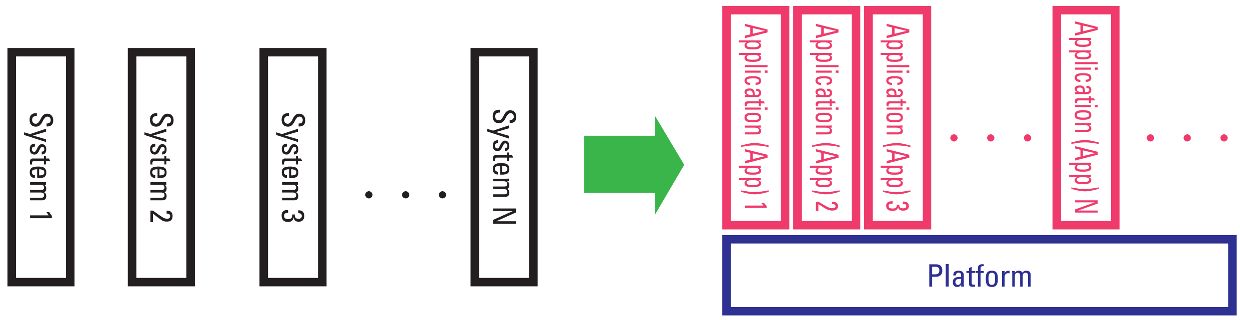


Figure 3. Platform-oriented. System implementation using applications running on a platform

In 2004, the Japan ITS Promotion Council released its "ITS Promotion Guidelines," the pillars of which are "safety and security, environment and efficiency, and comfort and convenience,"[4)] and represent a top level purpose-oriented concept with the main thrust being that each system is integrated and running on a platform. For examples of various projects see Reference 4.

The first stage of promotion was the practical use of the technology, the second stage was the dissemination and accelerated spread of the technology through society, and since 2010, the realization of a sustainable mobile environment has been promoted as the next generation of ITS's response to social issues. For the future of ITS, in light of the changes in both the societal and technical contexts, efforts continue toward the expansion of regional ITS and the realization of a next-generation mobility society. These efforts can be summed up in eight points:[4)]

1. Construction of a safe and secure transport system
2. Construction of a next-generation automobile society
3. A response to environmental needs
4. A response to the development of information and communication technologies
5. A response to the movement of next-generation people and goods
6. The introduction and promotion of an integrated regional ITS
7. Disaster response
8. A response to internationalization

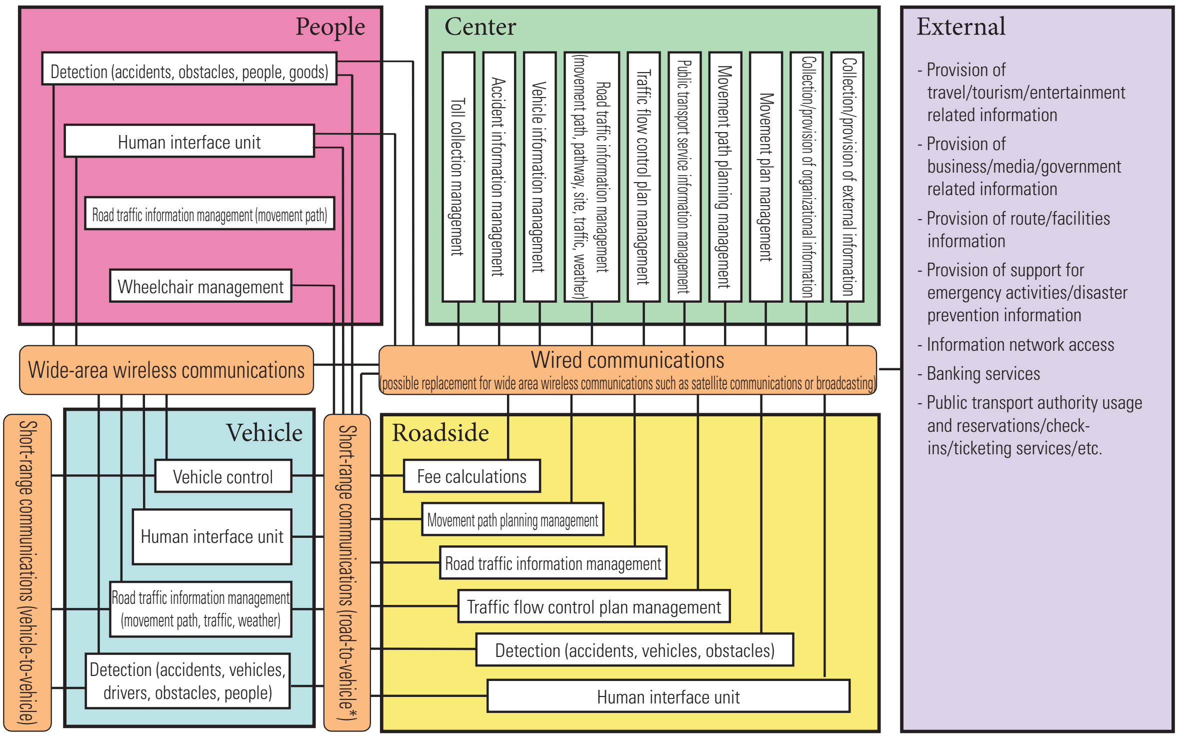
5.2.2 The history of related fields

Although the term ITS was coined in 1994, as previously mentioned, its origins can be traced back to the 1980s with programs that used sensing, information and communication, and signal processing and information processing to achieve a greater sophistication of traffic and transport, such as the Partners for Advanced Transportation Technology (PATH) Program in California in the United States and the PROgraMme for European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS) in Europe. Furthermore, if projects in Europe, America, and Japan such as automated driving, route guidance, and the provision of traffic information are included, the origins can be traced back to the 1950s.[5] Please refer to existing literature[6] that explains the needs and legislation required regarding the transition of research and development of automated driving, which began in the 1950s and comes up to the present day with Japan's ITS research and development projects on vehicle convoys traveling together in a line for increased energy efficiency.

5.2.3 System architecture

The system architecture conceptually represents interactions between the elements of each system and the system as a whole, as if laid out on a nautical chart, to achieve the system's objectives, and is intended to effectively advance the development of systems that require time to realize their large-scale practical applications and to spread through society. The purpose of system architecture development is to construct integrated systems efficiently, to ensure the scalability of the system, as well as to promote national and international standardization.

The system architecture in Japan that was formulated in the late 1990s (see Fig. 4) includes a complete picture (see Fig. 5) of the user service system, which is a premise of the plan.[7]



*Short-range communication (road-to-vehicle) indicates narrow range communication that takes place between the roadside and the vehicle/people.

Figure 4. System architecture (interconnected subsystems)[7]

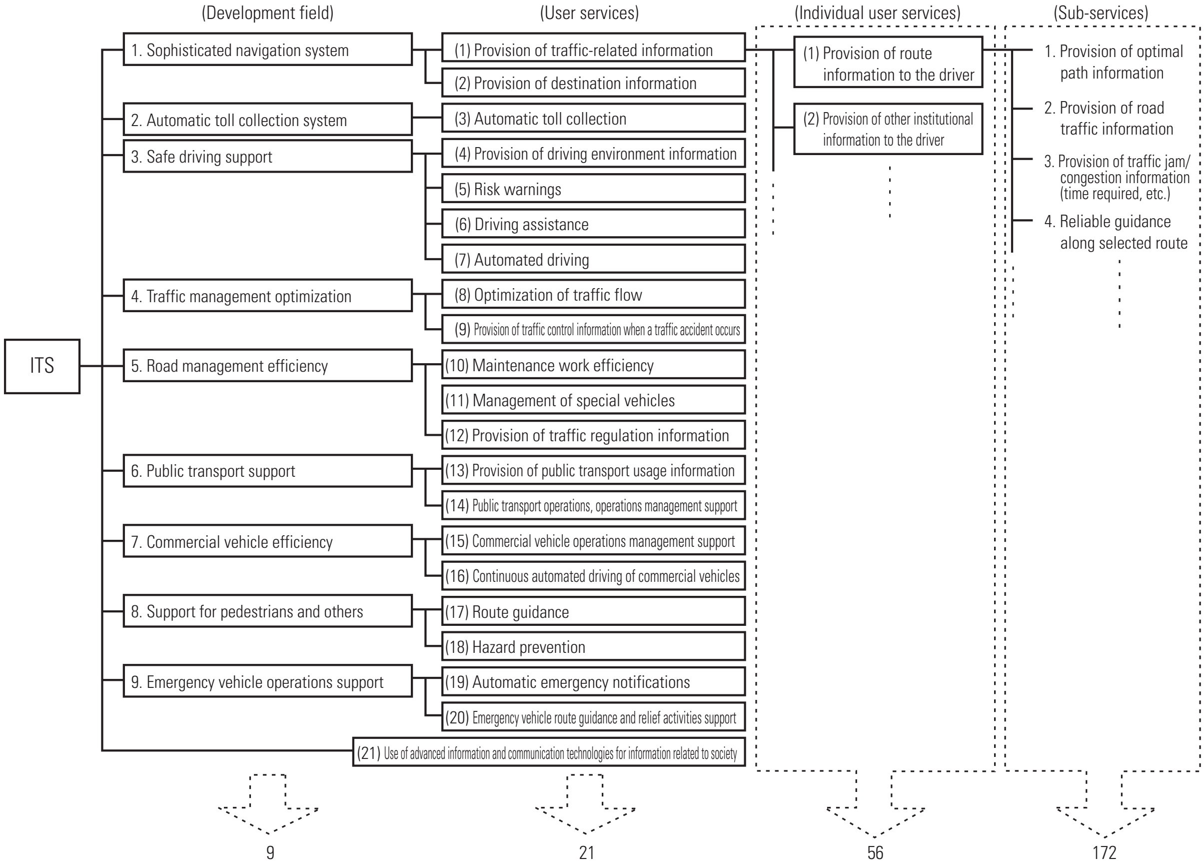


Figure 5. Overview of proposed system architecture development for user service system[7)]

5.3 ITS fields and research and development themes

5.3.1 Overview of the fields of ITS

The different fields of ITS, from their fundamental technologies to their surface applications, are many-layered and the expansion of these fields is similarly diverse. As Fig. 6 shows, the framework of ITS fields are supported by their respective fundamental technologies such as information and communication, positioning, and sensing, and there are numerous applications such as safe driving support services, traffic control services, and pedestrian services for the various functions provided by the

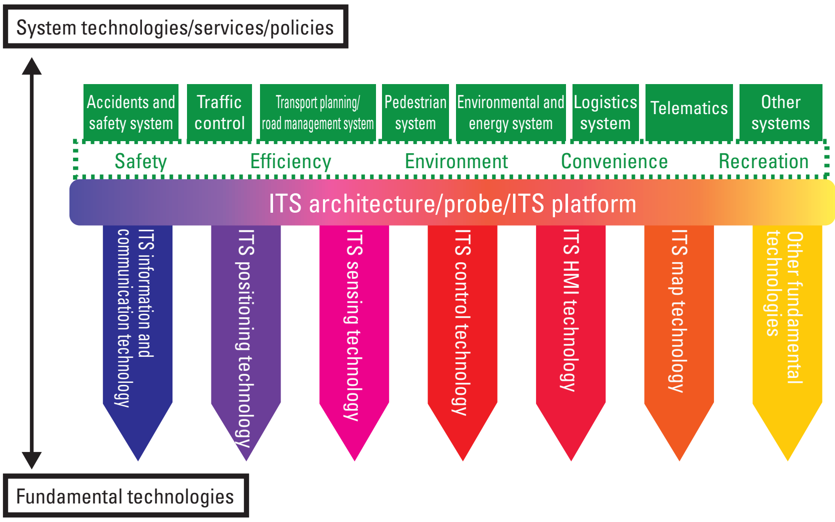


Figure 6. Framework of ITS fields

fundamental technologies in the middle layer of the platform.[8)]

The technologies that underlie the applications change with the passage of time. For example, the transition from dedicated information and communication, positioning, and sensing systems to all-purpose mobile phones, Wi-Fi, Bluetooth, and smartphones with built-in body sensing capabilities create the landscape in which new applications are released. In addition, the continued evolution of each fundamental technology and system technology also sees the evolution of the safe driving support system from simple danger warnings to assisted safe driving technologies to automated driving systems.

Figure 6 shows the universal and abstract concepts persistent through time from the fundamental technologies to the surface applications.

5.3.2 Changes in trends of the ITS world, and research and development themes

Originally, the essence of ITS was mostly awareness enhancement (Fig. 7). Safe driving support systems such as danger warning systems that inform the driver of risks looming beyond the range of their field of vision, wide-area real-time traffic information that cannot be known by drivers themselves, and the forecasting of potential areas of congestion all assist the driver in taking actions to avoid risks and inconveniences. They also inform drivers about current road surface conditions and can alert the driver thereby helping to prevent accidents. Technologies spread out from there to anti-lock braking systems (ABS) and collision avoidance systems assisting the driver in vehicle operation. Generally, these changes represent a transition from after-the-fact passive safety to before-the-fact active safety, paving the way for automated driving at various levels.

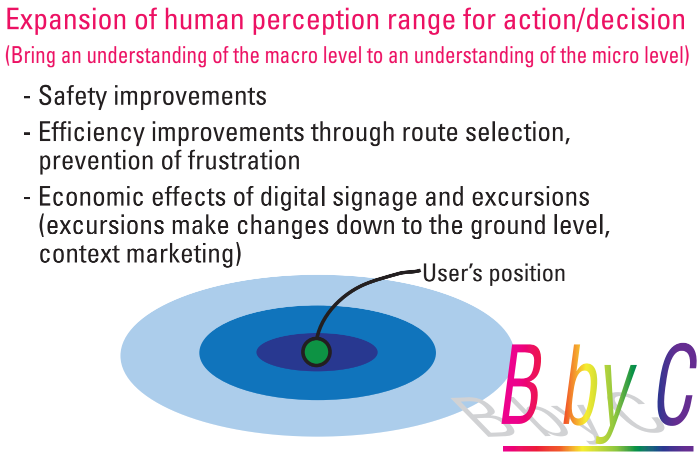


Figure 7. Awareness enhancement in the ITS fields

VICS is a system transmitting traffic information, and initially collected sensing data from relatively large road systems using infrastructure-mounted sensors such as loop coils or ultrasonic sensors. However, these data can fundamentally be collected only in areas close to the sensor locations. In contrast, systems developed over the past 10 years use probe car (floating car) data and then upload those data, including position, directly to servers on information networks. These systems are able to grasp traffic conditions by aggregating collected data and delivering traffic information to each vehicle. This method is able to select a single car from a group, and does not require any additional investment for infrastructure such as installing new sensors. The data collected are not limited by the installation positions of the sensor infrastructure, as long as the car passes a sensor, the data are collected. However, this type of probe system is not favorable overall. Although the installation locations of the infrastructure sensors are limited, the traffic data collected are fine-grained. In contrast, the probe system relies on absolute traffic volume and the proportion of sensors installed over the entire road system to determine the quality of the data. At lower traffic volumes the precision and accuracy of the data collected falls, and no data are collected at all if no vehicle containing a transmitter passes the target area, since a vehicle without a transmitter does not work as a probe.

One example of using this feature is the collection of probe car data immediately after the Great East Japan Earthquake on March 11, 2011. Figure 8 shows this example. The portions in blue show traffic data within a 24-h period after the earthquake. Note, however, that the figure does not always show the traffic data for all potentially passable roads, it simply shows four-wheeled passenger vehicles passing the sensor locations within a 24-h period. Furthermore, it does not show motorcycles or large transport vehicles using the roads; if a driver had not happened to use the road, no trace would have been recorded at all. It also does not show the passage of traffic on roads that are not colored blue. Yet, there is no doubt that these data were very important information in supporting activities during the disaster situation.

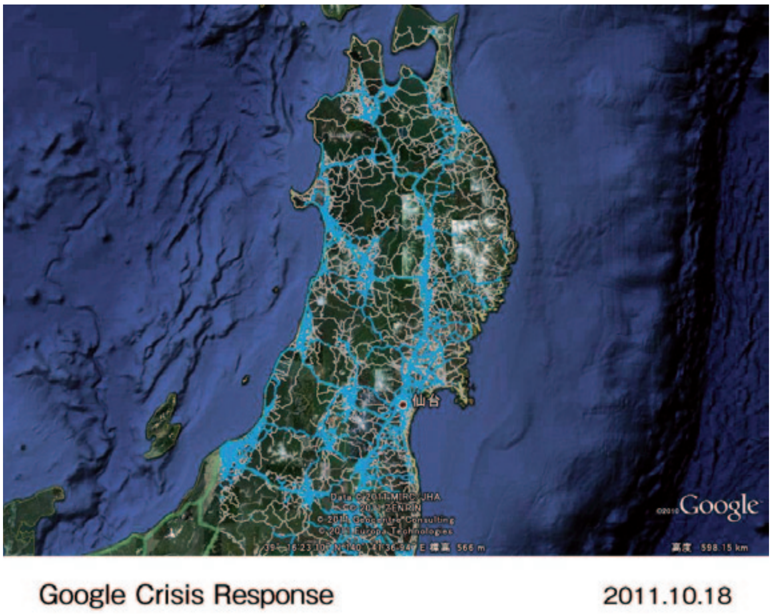


Figure 8. Example of probe information system (Honda Internavi traveling experiences immediately after the Great East Japan Earthquake)[9)]

A system using probes to gather data from smartphones is able to gather data with even finer granularity. While probes installed in vehicles provide data for only that single vehicle, probes transmitting from a smartphone can render extremely fine-grained position and direction data from people on buses, trains, and riding in cars; pedestrians on streets and in underground malls; and people inside buildings. It is also possible to process various pieces of uploaded data on the server side depending on conditions.

The use of smartphones as probes certainly reduces the size of the entity operating the system from the national level to the size of major companies, and in the future it is entirely feasible that this level will again be reduced to encompass small and medium-sized organizations.

In addition, even though smartphone applications may be partly inferior to a dedicated car navigation system, the fact that many applications can replace dedicated systems is a clear indication of the move toward lightweight solutions.

ETC is a system that automatically collects user toll fees to pay for road construction and maintenance costs from vehicles using the road, so for this purpose it is not absolutely necessary that the user's vehicle pass through a gate. It is possible to levy the toll using indexed routing information from the position data. If this is to become a reality, a system function preventing users from eluding the toll charge will become necessary.

Now, let us discuss the role of positioning infrastructure as a fundamental technology. There is no doubt that the most prevalent positioning infrastructure is GPS. However, in recent years, methods for acquiring specific position data by using the MAC address and RSSI of Wi-Fi access points are notably becoming the second-most used technique for acquiring location information and position information, representing positioning social infrastructure. With the addition of Bluetooth low-energy (BLE), positioning infrastructure has come to have a heterogeneous system structure. Similarly, this is also a contributing factor in the move toward lightweight solutions. Positioning using GPS requires a national-level endeavor; however, positioning using Wi-Fi and BLE has now become possible for companies and smaller organizations. Of course, there are both strong and weak points in the environment for the application of GPS, Wi-Fi, and BLE. GPS excels in outdoor environments, particularly in mountainous regions, at sea, and the like where there are few tall buildings. Wi-Fi is robust in urban areas, particularly where users are inside buildings or underground shopping centers. BLE exerts its strength indoors. This is an additional contributing factor in the movement toward lightweight solutions.

Finally, there are expensive dedicated vehicles for detecting the condition of road surfaces damaged by disasters. In contrast, by using the acceleration sensor information from smartphones attached to the dashboard, a system for detecting certain vibrations in the vehicle caused by damage to the road has been put to practical use. The sensor accuracy of the dedicated vehicle is high but the speed of the vehicle is slow. On the other hand, the accuracy in systems using smartphones is low but data are continually collected while the user is on the move. This is a further example of a lightweight solution.

5.3.3 Topics in 2014 and future development[4)]

ITS Japan has summarized the seven priority areas for the future development of ITS as follows:

1. The reduction of traffic accidents and road congestion to zero using advanced driver assistance systems
2. The resolution of challenges to efficient transport through a movement support information platform
3. The innovation of multimode transport to support mobility inside cities
4. The comprehensive management of road traffic
5. Increasing the efficiency of logistics
6. The optimization of energy use
7. The promotion of international cooperation

As shown in Fig. 9, the ITS World Congress of 2013 showcased ITS Green Safety. Figure 10 provides an overview of the basic shift toward automated driving, while Figure 11 illustrates the Green Wave Project, one of the National Police Agency's projects for FY 2014.

Due to space limitations the points above represent the general flow of ITS in Japan, see the following documents for more detailed information. See Reference 4 for the overall flow. See Reference 10 for information concerning the fundamental technologies, V2V and V2I information sharing (Connected Vehicles). As for information concerning positioning, the combination of GPS,[11)] gyros, dead reckoning, map matching, and other such methods alongside Wi-Fi access points,[12)] cellular base stations, and the platforms using those technologies have a variety of error-causing factors.[13)] Please refer to the indicated references for additional information, or see References 6, 14, 15, and 16 for information regarding

Figure 9. ITS Green Safety Showcases[4)]

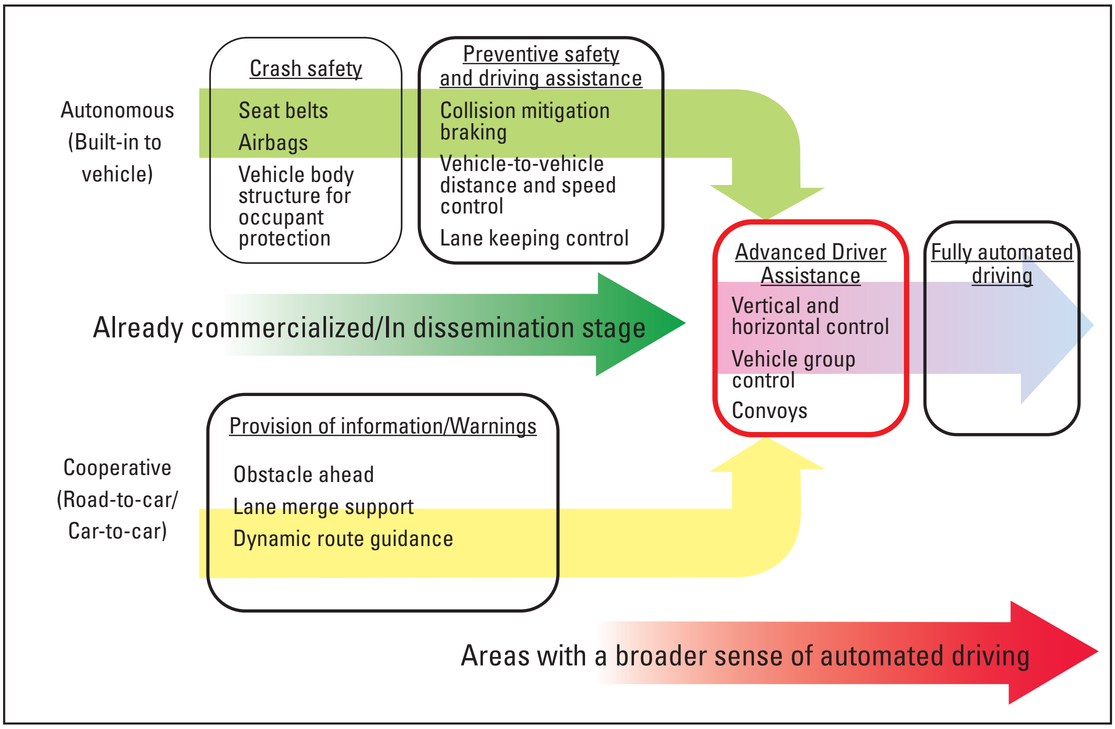


Figure 10. The basic shift toward automated driving[4)]

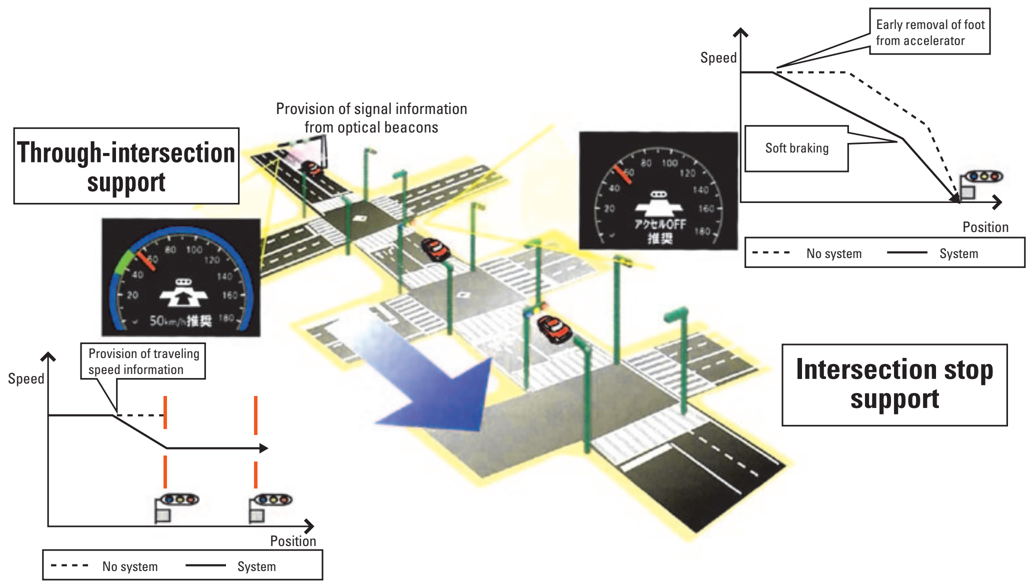


Figure 11. Examples of government ITS-related projects in FY 2014[4)]
(Source: National Police Agency)

automated driving from a variety of conceptual angles. Furthermore, although these may cover slightly different topics, see Reference 17 for information on location-based services from basics to practical applications, Reference 18 for electrical vehicle diffusion scenarios, and Reference 19 for design theory of new traffic systems.

An ITS is a sufficiently large-scale system to be referred to as a "system of systems" as described above, and looking at the system as a whole—from the fundamental technologies, to the system technologies, and ultimately to the services provided—we see it is in close contact with the real world, as a very wide ranging subject with a deep hierarchy. At its base exists a collection of vehicles and pedestrians, moving entities on the land, sea, and air, as well as positioning and information and communication. Furthermore, the actual concrete measures taken for positioning and information and communication sub-platforms suitable for mobile use will change with the times. In the past few years, a smartphone sensing sub-platform has been added, and dramatic changes have happened. It is necessary to cultivate the technologies that ITS use into the fundamental and system technologies that these forms of mobility require in order to help improve safety, enhance efficiency, reduce environmental load, boost convenience, and create more enjoyment through automated driving and big data processing. We need to become familiar with each individual technical field, and create a system that contributes to society through the mobility of people and things. To tackle such a wide breadth and such deep layers, readers are encouraged to deepen their knowledge on the fundamental and system technologies through the references provided in this chapter.

As for the future of ITS, it is necessary to provide ITS suitable for each region and promote the realization of a next-generation mobility society based on changes in social and technological conditions.

References
1) Ministry of Land, Infrastructure, Transport and Tourism. "ITS yogo shu" [ITS glossary]. Accessed November 6, 2014. http://www.mlit.go.jp/road/ITS/j-html/topindex/topindex_g02_4.html. (in Japanese)
2) ITS Japan. "About ITS." Accessed November 6, 2014. http://www.its-jp.org/english/about_e/.
3) European Commission. 1995. "Towards an intelligent transport system." *Community Research and Development Information Service*. Accessed November 6, 2014. http://cordis.europa.eu/news/rcn/3704_en.html.
4) ITS Japan. 2014. *Nihon no ITS: ITS nenji repoto 2014 nen ban* [Japan' ITS: ITS annual report 2014]. ITS Japan. (in Japanese)
5) Tsugawa, Sadayuki. 1999. "Communication Systems in the Intelligent Transport Systems". *The transactions of the Institute of Electronics, Information and Communication Engineers B* J82-B (11): 1958–1965. (in Japanese)
6) Tsugawa, Sadayuki. 2013. "Survey on Automated Driving Systems." *IATSS Review* Vol. 37, No. 3: 199–207. (in Japanese)
7) Japan Automobile Manufacturers Association, Inc. 2000. "ITS jitsugen no tame no sekkeizu: shisutemu akitekucha sakutei" [Plan to realize ITS: Drawing up a system architecture]. *JAMAGAZINE*, February. Accessed November 6, 2014. http://www.jama.or.jp/lib/jamagazine/200002/07.html. (in Japanese)
8) Hasegawa, Takaaki. 2005. "On systematization of the ITS field." *Journal of Institute of Electronics, Information and Communication Engineers* Vol. 104, No. 762 (ITS2004 89–97): 47–52. (in Japanese)
9) Honda Motor Co., Ltd. 2011. "Great East Japan Earthquake Traffic Information Maps Based on Honda Internavi Data Win 2011 Good Design Grand Award." *Honda Media Website*, November 9. Accessed November 6, 2014. http://www.hondanews.info/news/en/auto/4111109eng.
10) Ning, Lu, et al. 2014. "Connected Vehicles: Solutions and Challenges." *IEEE Internet of Things Journal* Vol. 1, No. 4: 289–99.
11) Kubo, Nobuaki. 2010. "Dai 5 sho: GPS ni yoru sokuteichi to gosa yoin" [Chapter 5: measured values by GPS and error factors]. Paper presented at the tutorial session for the Institute of Positioning, Navigation and Timing of Japan, April 22. Accessed November 6, 2014. http://www.denshi.e.kaiyodai.ac.jp/jp/assets/files/pdf/content/201004.pdf. (in Japanese)
12) Ito, Seigo, and Nobuo Kawaguchi. 2006. "Wireless LAN Based Hybrid Positioning System Using Bayesian Inference and Access Point Selection." *IEEJ Transactions on Electronics, Information and Systems* Vol. 126, No. 10. (in Japanese)
13) Hasegawa, Takaaki, Tetsuya Manabe, Katasuharu Hosoe, and Kazuo Mizuno. 2014. "Positioning Social Infrastructures from the Viewpoint of System Innovation: Applications and Smartphone Positioning Using GPS/Wi-Fi/BS." *IEICE Technical Report* (ITS 2013-76): 69–78. (in Japanese)
14) National Highway Traffic Safety Administration. 2013. "Preliminary Statement of Policy Concerning Automated Vehicles." Press Releases, May 30. Accessed November 11, 2014. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.
15) Furukawa, Osamu, et al. 2014. *Jidosha oto pairotto kaihatsu saizensen: yoso gijutsu kaihatsu kara shakai infura seibi made* [Frontline development of autopilot systems for automobiles: From underlying technology development to social infrastructure development]. NTS. (in Japanese)
16) Petit, J., and S. E. Shladover. 2014. "Potential Cyberattacks on Automated Vehicles." *IEEE Transactions on Intelligent Transportation Systems*. http://dx.doi.org/10.1109/TITS.2014.2342271.
17) Küpper, Axel. 2005. *Location-based Services: Fundamentals and Operation*. Wiley.
18) Hasegawa, Takaaki. 2010. "Diffusion of Electric Vehicles and Novel Social Infrastructure from the Viewpoint of Systems Innovation Theory." *IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences* E93-A, No. 4: 672–678.
19) Hasegawa, Takaaki. 2013. "A Design Theory for New Transport Systems." *IATSS Review* Vol. 37, No. 3: 224–232. Accessed November 6, 2014. http://www.iatss.or.jp/common/pdf/publication/iatss-review/37-3-09.pdf. (in Japanese)

Practical application projects for reference

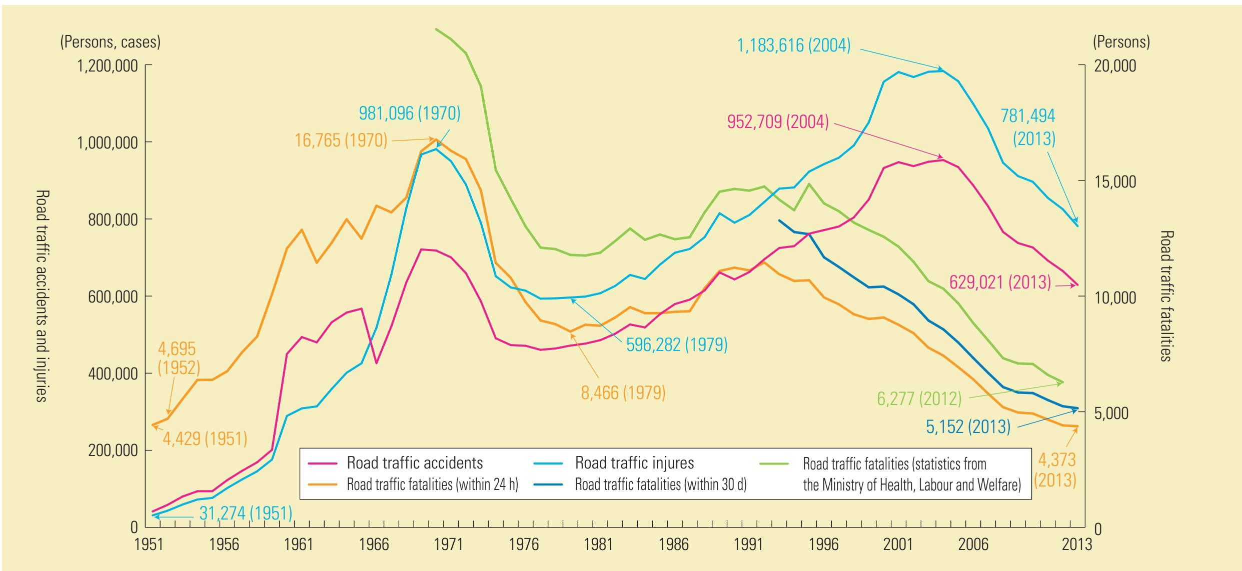
Practical application of a public involvement-type system for planning and evaluating road traffic safety measures: 160–163

Chapter 6 The image of automobile safety

6.1 Changes in traffic accident statistics and safety measures

Chapter 6 considers the issue of automobiles in road traffic, reflecting on the history of safety improvement technology initiatives and clarifying the image of safety that serves as the end goal. To begin, we reexamine the traffic accident statistics, which form the background for this issue.

Figure 1[1)] shows annual changes in the number of traffic accidents in Japan. Looking at the long-term trend of traffic fatalities from 1951 to 2013, there are two noticeable peaks. These increases and decreases are closely associated with the growth and social situation of the traffic society. The rapid



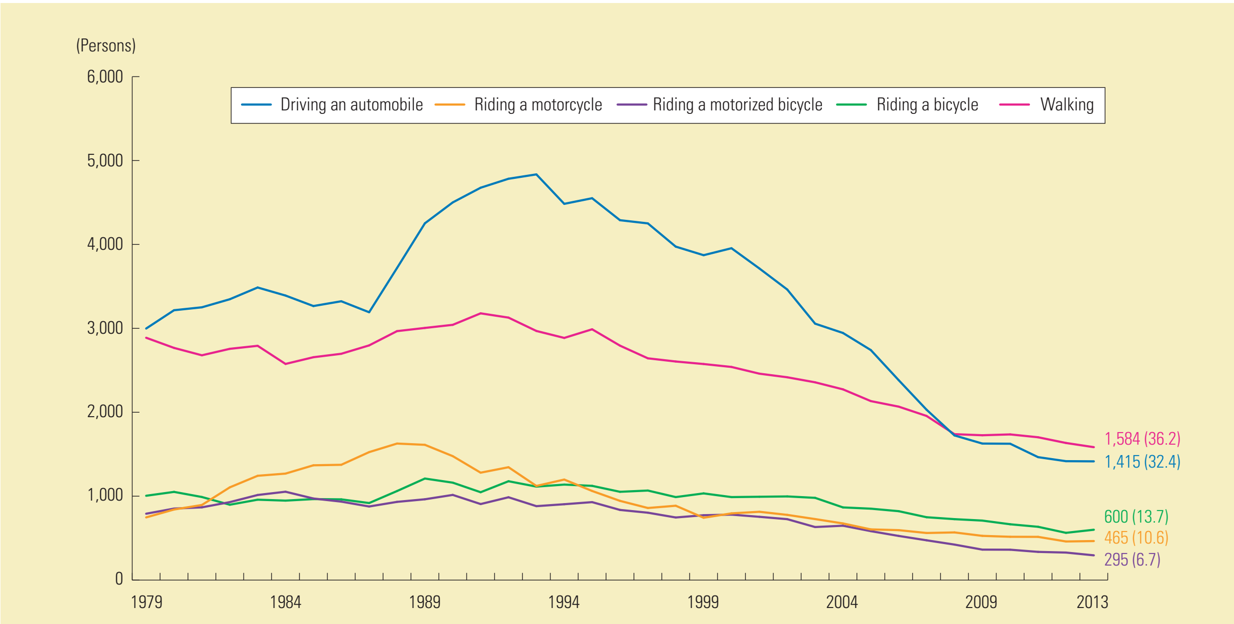
Note 1: Based on documents issued by the National Police Agency.
Note 2: Accidents involving property damage are not included in the number of cases after 1966. Okinawa Prefecture was not included in the survey until 1971.
Note 3: According to Article 2, Paragraph 1, Item 1 of the Road Traffic Act, "24-h fatalities" are persons who died within 24 h of a road traffic accident such as those involving automobiles, trains, or other vehicles.
Note 4: "Thirty-day fatalities" are persons who died within 30 days of a traffic accident (inclusive of 24-h fatalities).
Note 5: Fatalities in the statistics of the Ministry of Health, Labour and Welfare were provided by the National Police Agency based on the vital statistics collected by the Ministry of Health, Labour and Welfare. The number represents fatalities due to traffic accidents in the reference year and excludes persons who died after more than 1 year or due to accident-related aftereffects. Before 1995, all automobile accidents are included, but the number for years later than 1995 is calculated by subtracting the number of fatalities due to non-road traffic accidents from the number of fatalities due to traffic accidents on land.

Figure 1. Number of traffic accidents, fatalities, and injuries on Japanese roads[1)]

increase that begins in the 1950's and culminates in a peak of 16,765 deaths (within 24 hours of accident) and 981,096 injuries in 1970 is what is informally called "Traffic War I." Factor analysis of the situation indicates that it is the result of insufficient road maintenance, improvements, and traffic safety facilities for the increased traffic loads caused by a rapid increase in private four-wheeled automobile ownership. Other contributing factors include the change in consciousness of traffic participants not keeping up with the rapid changes in the traffic society as well as insufficient technologies for ensuring the safety of vehicles.

For this reason, the Traffic Safety Policies Basic Act was enacted in 1970 to promote traffic safety measures throughout the country. To account for the slow pace of changes in consciousness by traffic participants, countermeasures at the time promoted vehicle–pedestrian separation, such as through the creation of footbridges in addition to crosswalks and traffic signals, and through creation of guardrails (see Reference 2 for details of traffic facilities at the time). Automobile safety features such as those in the Experimental Safety Vehicle, as will be discussed later, began to be considered, and beginning in April 1969, driver's seat safety belts became required in all domestically manufactured passenger vehicles. The requirement for safety belts would later be extended to passenger seats, and then to rear seats. As a result of these measures, the number of fatalities trended downward until 1979 from its 1970 peak.

Following that, further increases in the number of privately owned automobiles and of driver's license holders resulted in a corresponding increase in automobile-kilometers travelled, creating a second upward trend in traffic accidents. There was a particularly noticeable increase in automobile-kilometers travelled over the five-year period of economic prosperity beginning in 1986. Figure 2 shows the results, with the number of passenger vehicle accident fatalities[1] once again surpassing the 10,000



Note 1: Based on documents provided by the National Police Agency ("Other" is not shown).
Note 2: Number in parentheses indicates the percentage of all injuries for that mode of transportation.

Figure 2. Changes in the number of traffic accident fatalities by mode of transport[1]

(within 24 hours) mark. This period is referred to as “Traffic War II.”

To address this and reduce the number of passenger vehicle fatalities, automobile safety measures such as anti-lock braking systems and airbags were promoted and became more common (Fig. 3[3)]). In 1992, driver and passenger seatbelt usage in general road driving was made mandatory, and increased seatbelt usage rates along with improvements to emergency care systems had the effect of decreasing accident fatality rates (within 24 hours) following the peak in 1993 (Fig. 1[1)]). Note, however, that in contrast to the situation in the 1970s, the number of traffic accidents and injuries continued to increase for 10 years after the peak in 1993. This is because improvements to automobile safety features and emergency care systems lowered the fatality rates of serious accidents, meaning that those who would have died in the 1970s setting were instead only injured.

Beginning in 2004, there has been a further reduction in the number of traffic fatalities alongside a reduced number of traffic accidents, due to a number of factors including the dissemination of vehicle safety technologies such as collision mitigation braking systems and skid prevention devices, promotion of automotive development through public evaluation of collision safety performance by car assessment programs, increased penalties for drunken driving, increased rates of seatbelt usage, improvements in driver courtesy such as reduced speeding rates, and a reduced number of automobile-kilometers driven. As of 2013, the number of annual traffic accidents is holding steady at approximately 600,000.

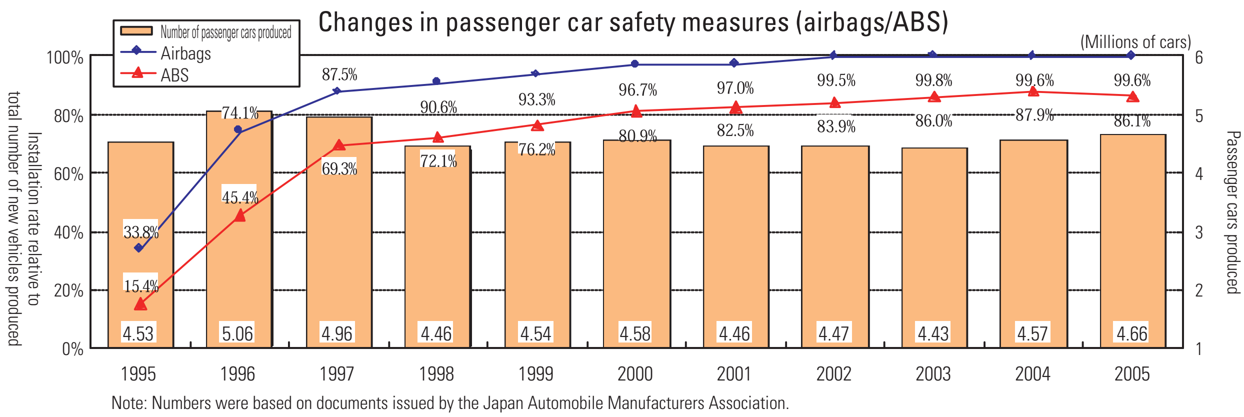


Figure 3. Changes in passenger car safety measures (airbags/ABS)[3)]

The increasingly aging society in Japan of recent years has resulted in changes in traffic accident trends. Since 2008 in particular, there has been a reversal in the number of pedestrian and automobile passenger fatalities (Fig. 2). Examining the number of traffic accident fatality rates by conditions and age (Fig. 4[1)]), one can see a remarkable increase in the ratio of deaths of age 65 and older pedestrians in accidents involving automobiles. Older people now have higher driver’s license possession rates, resulting in a trend of increased traffic fatalities involving elderly (age 75 or older) drivers.[4)]

Given these trends in traffic accidents of recent years, the 9th Traffic Safety Basic Plan of the Cabinet Office places a high emphasis on preserving the safety of pedestrians and cyclists along residential roads, the primary living environment for the elderly.[5)] Recent automotive safety features to accommodate these changes include alterations to vehicle nose shapes and pop-up hood systems as well as other vehicle body structural modifications for the reduction of injury in the event of a pedestrian collision. Low-speed collision avoidance braking systems that can reduce the severity of impact with pedestrians and cyclists are also increasingly being deployed.

Automotive safety technology development is thus proceeding based on traffic accident factor analysis, and development and deployment of these technologies are helping to reduce the number of traffic accidents. In the next section we will take a closer look at trends in safety technology development over each era.

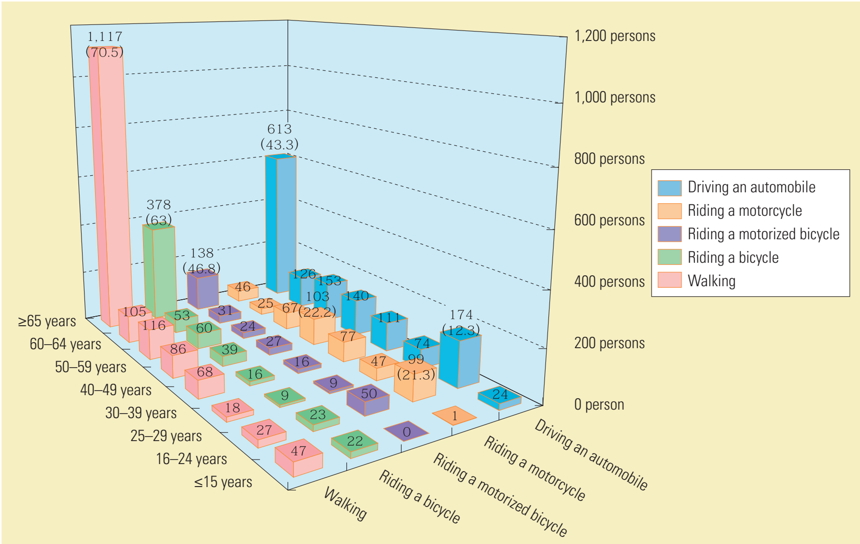


Figure 4. Number of traffic fatalities by mode of transportation and age group[1)]

6.2 History and trends of automobile safety technology development

6.2.1 The dawn of safety measures: The ESV

As discussed above, the 1960s was an era of rapid motorization, not only in Japan but also in many countries throughout the world, and around this time traffic safety attracted increased attention. To improve the state of traffic safety, in 1970 the National Highway Traffic Safety Administration of the U.S. Department of Transportation proposed development of the ESV, a test vehicle incorporating state-of-the-art car safety technology. With the goal of reducing vehicle occupant fatalities, the ESV would target technological advances for protecting occupants and aiding danger avoidance by drivers. In the U.S. at the time, 60% of traffic fatalities were of passengers, so the U.S. plan may have been aimed at reducing these numbers through passenger protection in the event of collisions.[6)]

In November 1970 the governments of the United States, Japan, and then West Germany exchanged an agreement to implement the plan, bringing Japan into the project. At the time, the U.S. planned for standards based on a vehicle weight of approximately 1800 kg. In Japan, however, a special committee in 1971 considered and determined separate specifications for small vehicles—a 1150-kg four-seat vehicle and a lighter 900-kg two-seat vehicle—and put out a call for developers. The Japanese standards aimed to include a survival space in which occupants could expect to survive a head-on or rear-end collision at speeds of up to 80 km/h, and included other preventative safety features for accident avoidance. Another feature of the Japanese standards is that they called for adherence to both the Japanese Road Trucking Vehicles Act and to the U.S. Federal Motor Vehicle Safety Standards.

The following presents specific examples of some of the safety technologies developed as part of the

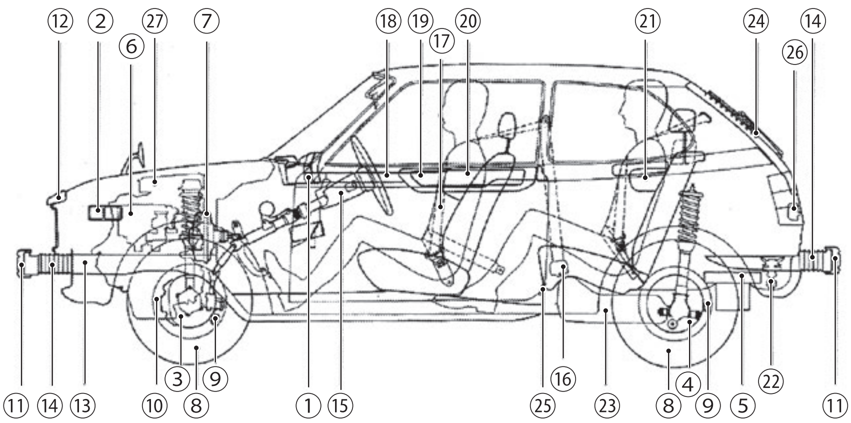
ESV program.

One such advance was improvements to vehicle construction designed for absorbing energy in frontal impacts of up to 80 km/h. These include the adoption of impact energy-absorbing frames and pillars and side beams designed to preserve a survival space for passengers.[7)] To aid in calculating these new frame designs, engineers in the U.S. used NASTRAN, a finite element method application developed as part of NASA's Apollo Program and released free of charge thereafter for private technology transfer. It is notable that the techniques used for body rigidity and similar calculations today got their start in this early application for automobiles.

Another advance resulting from the ESV program was airbags. There had been previous proposals for collision detection technologies coupled with safety cushioning, but none had yet been realized. At the same time as the ESV program, proposals for the mandatory use of seatbelts were being debated, which increased demands for a passive restraint system that could mitigate the force of collisions without the use of seatbelts. This provided a reason for airbags to be considered as part of the ESV program. This led to General Motors bringing to market the world's first mass-produced automobile equipped with an airbag system.

There were also advances toward better accident avoidance, such as an anti-skid braking system (now called anti-lock braking), and sideslip-limiting features (now called electronic stability control). These two systems together significantly improve vehicle stability when braking.

Participating companies developed and implemented performance evaluations on several test vehicles through the ESV program, which was generally complete by the time of its 5th International Conference in 1974. The program was successful in its goals of actually producing a test vehicle that included the state-of-the-art technology of the time, but these efforts were undertaken without consideration of



① Centralized warning and action indicator system ② Dual-sided turn signals ③ Anti-lock disk brake system
④ Anti-lock drum brake system ⑤ Electronic control unit for anti-lock brake system ⑥ Anti-lock brake actuator ⑦ Vacuum booster
⑧ Safe tires ⑨ Tire inner pressure monitoring system ⑩ Automatic transmission ⑪ Bumper with urethane pad
⑫ Urethane pad ⑬ Energy-absorbing frame structure ⑭ EAU ⑮ Impactless steering wheel and column
⑯ Webclamp emergency locking retractor ⑰ Energy-absorbing belt ⑱ Door reinforced with beams ⑲ Energy-absorbing side pads
⑳ Shoulder pads ㉑ Retractable shoulder pads ㉒ Current-blocker ㉓ Fuel tank ㉔ Emergency exit ㉕ Emergency exit lever
㉖ Emergency exit lock ㉗ CVCC engine

Figure 5. Experimental safety vehicle (structural diagram of the Honda ESV)[9)]

manufacturability or costs. The Research Safety Vehicle Program based on consumption trends and mass productivity took over where the ESV left off, but now focuses its consideration on developing issues such as energy shortage and environmental concerns.[8] The numerous safety features that began as part of the ESV program and are now implemented in actual production vehicles (Fig. 5[9]) are a testament to the significant role it played in the development of new safety-related technologies.

6.2.2 The Advanced Safety Vehicle

Figure 6 shows trends from 1970–1990 for Japanese, U.S., and European projects related to intelligent transport systems (ITS). From this figure, one can see that there were various Ministry-sponsored projects now linked to current ITS that began in the late-1980s Japan, encompassing the Traffic War II period.

Among these projects, the one relating to vehicles is the Advanced Safety Vehicle (ASV) program, which began from the Japanese Land, Infrastructure and Transportation Ministry. The project has been ongoing since 1991, and as of 2014 is now in its fifth five-year plan. The project is guided by a review committee that includes representatives from among academic experts, affiliated organizations, relevant ministries and agencies, and fourteen automobile and motorcycle manufacturers. Table 1 shows an overview of the ASV program's promotional plan for each period.

The ASV program aims at preventing accidents and reducing damage due to collisions through implementation of electronic control technologies that were rapidly developing in the 1980s, and furthermore by establishing the technological foundation for vehicle-side ITS features. ASV vehicles therefore feature a variety of sensors (Fig. 7) and control mechanisms.

The program's first period (1991–1995) was largely focused on technological considerations for

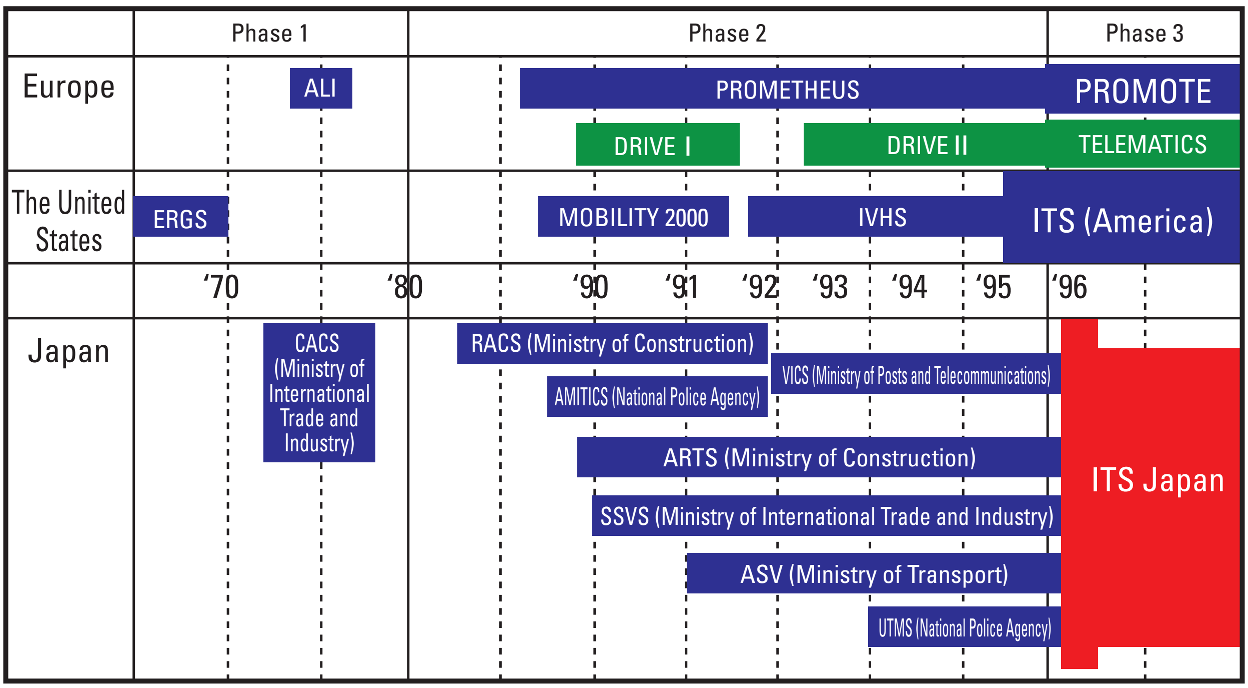


Figure 6. Early phases of the ITS-related projects (organization names are for the indicated year)

Table 1. Outline of timeline for ASV promotion[10]

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
1991–1995	1996–2000	2001–2005	2006–2010	2011–2015
• Proving technological feasibility	• Research and development for commercialization	• Investigation for promotion and marketing • Development of additional technologies	• Full-scale marketing • Partial commercialization of the communication-based safety system	• Dramatic advancement
• Single vehicle (self-sensing type)	• Single vehicle (self-sensing type) • Vehicle-infrastructure cooperation	• Single vehicle (self-sensing type) • Vehicle-infrastructure cooperation	• Single vehicle (self-sensing type) • Links with other vehicles • Vehicle-infrastructure cooperation	• Dramatic advancement in commercialized ASV technology • Next-generation communication-based driving • Development and marketing of the support system

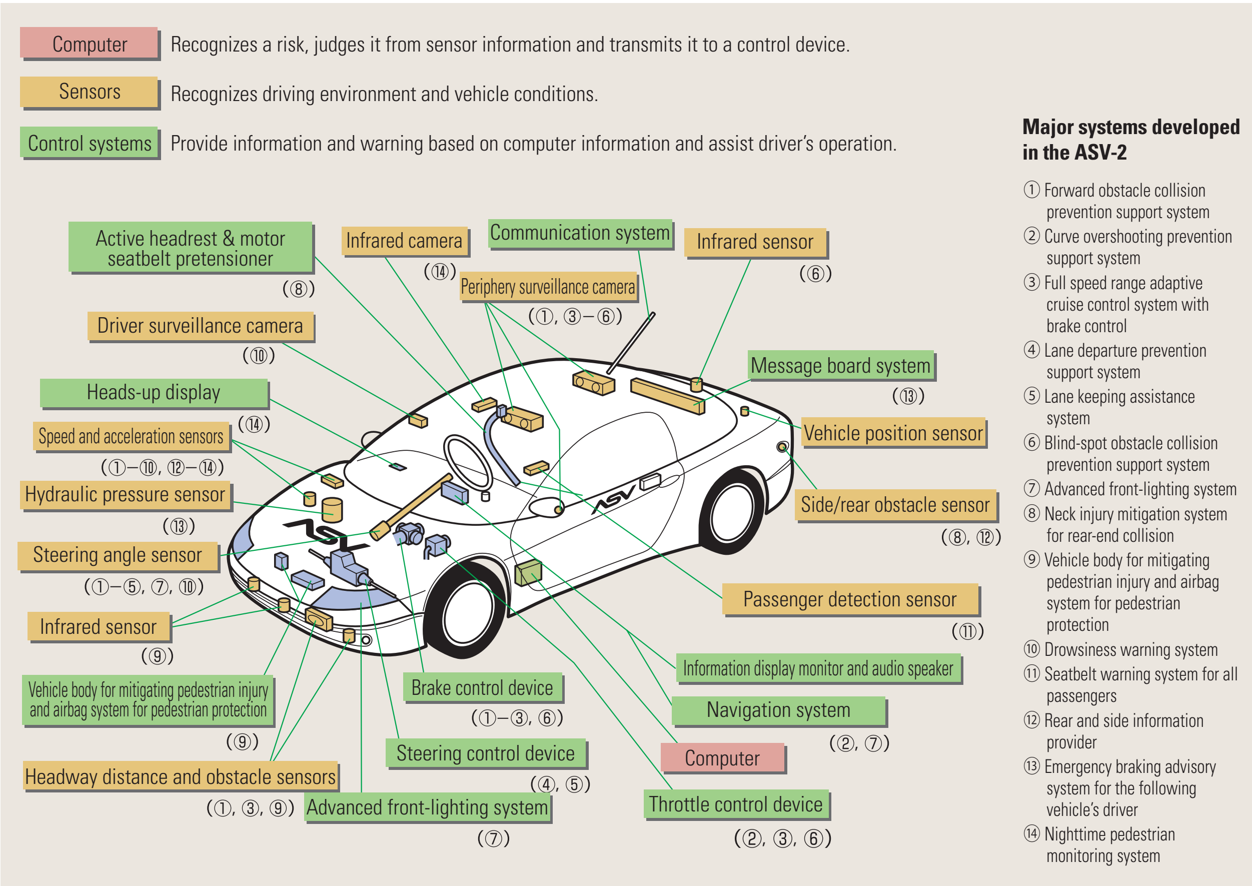


Figure 7. Schematic of ASV[11]

passenger cars, but starting with the second period (1996–2000) extended to large trucks and motorcycles. Another characteristic of the second period is that it marks the point when international ITS research began to take off. In the ministry publication *Comprehensive Plan for Intelligent Transport Systems*, published in July 1996, the ASV was promoted as a part of "support for safe driving." Cooperation between the vehicle and the road infrastructure was also considered, and in October 2000 cooperative verification experiments were performed at the Ministry of Land, Infrastructure and Transport's Public Works' Research Institute (formerly the Ministry of Construction's Public Works Research Institute) in Tsukuba, Ibaraki Prefecture. These experiments aimed to test driver acceptance and the appropriateness

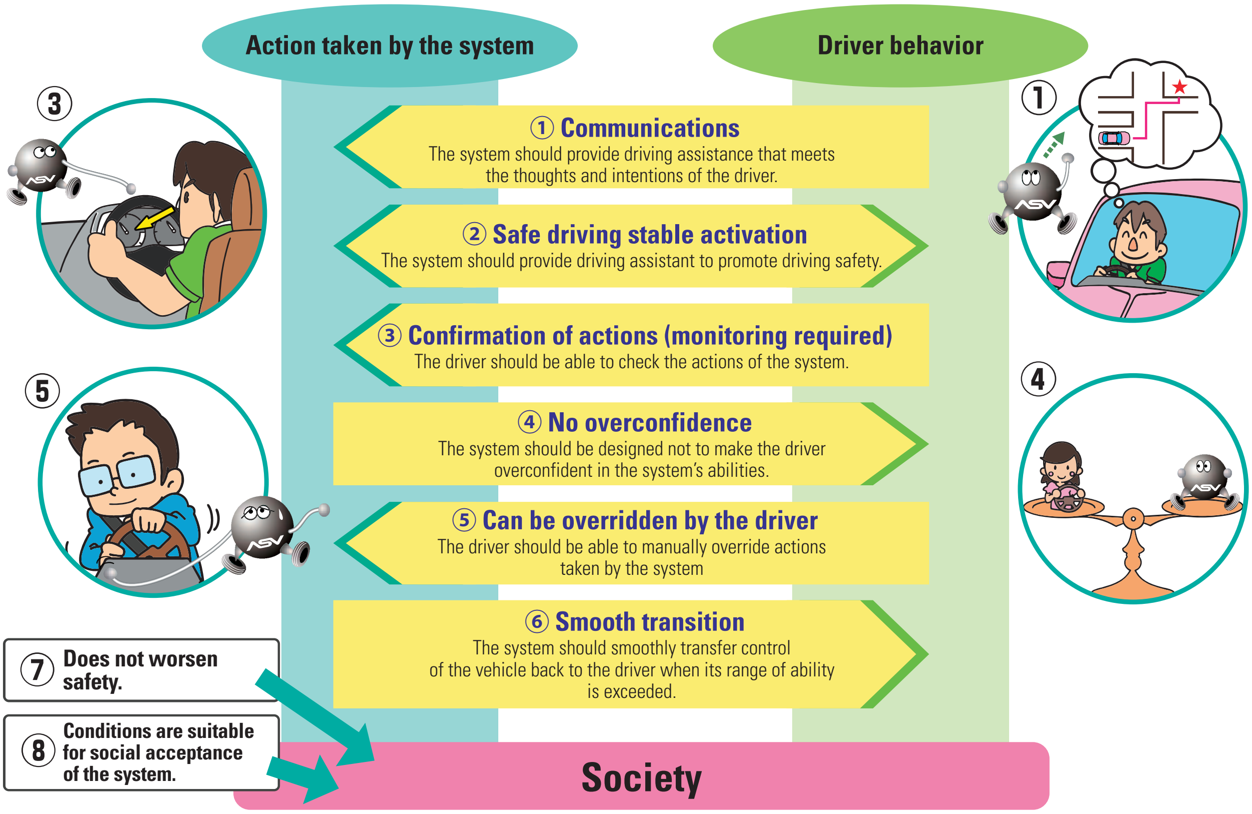


Figure 8. Flow of driving assistance[12)]

of road infrastructure for seven services for integration with an advanced cruise-assist highway system: forward obstacle collision prevention, curve approach risk prevention, lane departure prevention, intersection collision prevention, right turn collision prevention, crosswalk pedestrian collision prevention, and vehicle spacing maintenance through use of road surface information.

The third period (2001–2005) was largely concerned with advancing promotion of the ASV. At this time, the "Design principles of ASV" that were developed in the second period were concretely compiled into "concepts for driving assistance" (Fig. 8[12)]). With regards to "retaining driver acceptance," for example, it is important that the driver be able to confirm system operations. A "principle for driver assistance" clarifies that it is the driver who must be the central component of safe driving, and that ASV technologies are intended only to serve a sideline support role. This principle requires that in actualized devices there must be a driver-operable switch that enables operation of the assistance system, and that even when the system is enabled, it must be possible for the driver to forcefully intervene. To ensure system integrity, this principle for driver assistance will need to be incorporated as part of the legal preparations for actualization of the automatic driving systems that are currently under development.

Basic system designs for driving support systems that incorporate communications were taken up in the fourth period (2006–2010), and are being used in vehicle surroundings recognition support services that use vehicle-to-vehicle communications for accident avoidance, and are expected to reduce the number of accidents at intersections and during turns. Also under consideration are accident prediction applications using accident analysis to monitor driver state in commercial vehicles to prevent the health-related accidents that are a social problem in the current age.

6.2.3 The future of the ITS concept

As described in the previous section, automotive technologies using electronics and communications technologies for reducing accidents and improving safety have an important position in the ITS field. The ITS interim plan (2011–2015) created by ITS Japan in 2011 calls for a next-generation mobility system that integrates traffic networks, energy networks, and communications networks.[13] Of particular note is that as a result of the 2011 Great East Japan Earthquake, the report specifies the need for construction of an ITS-based information infrastructure that remains usable in times of disaster. Another development is that of systems combining ASV and communications technologies for vehicle-to-vehicle communications through multi-POP routing, for example, to realize information sharing related to other vehicles in the vicinity or road conditions ahead, thus ensuring the safety of entire groups instead of just individual cars. Such advance sharing of information related to potential risks and dangers will likely reduce the number of traffic accidents. The development of new support technologies for pedestrians, cyclists, and new forms of mobility will also help to compensate for the effects of driver inexperience and cognitive decline due to aging, helping to realize a transportation society through which all members can safely move.[14]

At the 20th ITS International Conference held in Tokyo in 2013, various companies gave demonstrations of their automatic driving systems, indicating that realization of these systems is now well supported at the government level.[15] A summary roadmap clearly defines the driving support and automated operation systems presented in the previous section regarding ASV (Table 2), and strategies such as unification of autonomous and cooperative systems are listed along with items of emphasis.

Table 2. Definition of driving safety support and automatic driving systems[15]

<table>
<tr><th colspan="2">Category</th><th>Overview</th><th colspan="2">Corresponding system</th></tr>
<tr><td colspan="2">Information provided type</td><td>Warning the driver, etc.</td><td colspan="2" rowspan="2">Driving safety support system</td></tr>
<tr><td rowspan="4">Automated type</td><td>Level 1: Single operation</td><td>The vehicle performs acceleration, steering, or braking.</td></tr>
<tr><td>Level 2: Complex system</td><td>The vehicle performs one or two acceleration, steering, and braking operations simultaneously.</td><td rowspan="2">Semi-automated driving system</td><td rowspan="3">Automated driving system</td></tr>
<tr><td>Level 3: Advanced system</td><td>The vehicle performs all acceleration, steering, and braking operations (emergency response: driver).</td></tr>
<tr><td>Level 4: Fully automated driving system</td><td>The vehicle (not the driver) performs all acceleration, steering, and braking operations.</td><td>Fully automated driving system</td></tr>
</table>

References

1) Cabinet Office. 2014. *Heisei 26 nenban kotsu anzen hakusho* [White paper on traffic safety in Japan 2014]. Accessed December 10, 2014. http://www8.cao.go.jp/koutu/taisaku/h26kou_haku/zenbun/index.html. (in Japanese)
2) Fukuda, Atsushi et al. 2011. "Kotsu senso eno torikumi: tojo koku ni koken shiuru nihon no keiken to chiken" [Managing traffic war: Japan's experience and knowledge that can contribute to solving traffic issues in developing countries]. *Heisei 22 nendo kenkyu chosa hokokusho* [Research report 2012]. International Association of Traffic and Safety Sciences. (in Japanese)

3) The National Police Agency, Traffic Bureau. 2007. *Heisei 18 nen chu no kotsu shibojiko no tokucho oyobi doro kotsuho ihan torishimari jokyo ni tsuite* [Characteristics of fatal traffic accidents and effectiveness of traffic violation control]. (in Japanese)
4) Institute for Traffic Accident Research and Data Analysis. 2012. "Kotsu tokei heisei 24 nen ban." [Statistics for traffic 2012]. Accessed December 10, 2014. http://www.itarda.or.jp/. (in Japanese)
5) Cabinet Office. 2011. "Dai 9 ji kotsu anzen kihon keikaku." [Traffic safety basic plan 9]. Accessed December 10, 2014. http://www8.cao.go.jp/koutu/kihon/keikaku9/. (in Japanese)
6) Okami, Yoshiro. 1976. "Safety and the ESV Program." *IATSS Review* Vol. 2, No. 2: 132–140. (in Japanese)
7) Toyota Motor Corporation. "Toyota jidosha 75 nenshi" [75 years of Toyota]. Accessed December 10, 2014. http://www.toyota.co.jp/jpn/company/history/75years/text/index.html. (in Japanese)
8) Sano, Shoichi. 1979. "ESV Program and the Perspective of Study on Automobile Safety." *IATSS Review* Vol. 5, No. 4: 300–305. (in Japanese)
9) Society of Automotive Engineers of Japan, ed. 2009. *Jidosha no hyakka jiten* [Encyclopedia of automobiles]. Maruzen Publishing. (in Japanese)
10) Ministry of Land, Infrastructure, Transport and Tourism. *ASV suishin keikaku ni tsuite* [About ASV Promotion Program]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/aboutasv.html. (in Japanese)
11) Ministry of Land, Infrastructure, Transport and Tourism. 2002. *Dai 3ki ASV suishin keikaku panfuretto* [ASV Promotion Program pamphlet (Third period)]. (in Japanese)
12) Ministry of Land, Infrastructure, Transport and Tourism. 2011. *Dai 5ki ASV suishin keikaku panfuretto* [ASV Promotion Program pamphlet (Fifth period)]. (in Japanese)
13) ITS Japan. 2011. *ITS Shin chuki keikaku (2011–2015 nen) no sakutei* [Development of a new midterm ITS plan 2011–2015]. Accessed December 10, 2014. http://www.its-jp.org/katsudou_old/katudou170/. (in Japanese)
14) ITS Japan. 2013. *ITS niyoru mirai sozo no teigen: daredemo dokodemo kaiteki ni ido dekiru shakai no jitsugen* [Recommendations of the creation of the future by ITS: creating the society that provides everyone with access to any place with comfort]. Accessed December 10, 2014. http://www.its-jp.org/document/20131017/ITS-future-vision_j_131010.pdf. (in Japanese)
15) IT Strategic headquarters. 2014. *Kanmin ITS koso/rodo mappu* [Government and people ITS framework/roadmap]. (in Japanese)

Recommended Reading

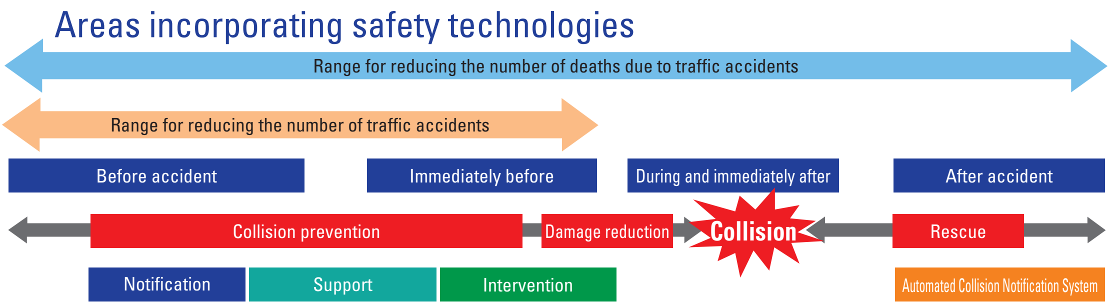
1) Ministry of Land, Infrastructure, Transport and Tourism. "ASV ni kansuru kenkyu seika hokokusho" [Results of research on ASV]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/index.html. (in Japanese)
2) Ministry of Land, Infrastructure, Transport and Tourism. 2001. "Senshin anzen jidosha (ASV) suishin keikaku (dai 2 ki) ni kansuru hokokusho" [Report on promotion plan for advanced safety vehicles (2nd stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv2report.pdf. (in Japanese)
3) Ministry of Land, Infrastructure, Transport and Tourism. 2006. "Senshin anzen jidosha (ASV) suishin keikaku hokokusho: dai 3 ki ASV keikaku ni okeru katsudo seika ni tsuite" [Report on the promotion plan for advanced safety vehicles: results of ASV promotion plan (3rd stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv3seikahoukokusyocorrection.pdf. (in Japanese)
4) Ministry of Land, Infrastructure, Transport and Tourism. 2011. "Senshin anzen jidosha (ASV) suishin keikaku hokokusho: dai 4 ki ASV keikaku ni okeru katsudo seika ni tsuite" [Report on the promotion plan for advanced safety vehicles: results of ASV promotion plan (4th stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv4pamphlet_seika.pdf. (in Japanese)

Chapter 7

Technologies for safety improvement

7.1 Passenger vehicles

This section categorizes by features various technologies for realizing the safety image presented in Chapter 6 and introduces the technologies with respect to each category of vehicle. We also describe the implementation timing for the devices shown in Fig. 1, mainly for passenger vehicles.



Active safety		Pre-collision safety	Passive safety	
Preventive Safety	Accident avoidance	Pre-collision safety	Injury reduction	Damage mitigation
ACC LKA AFS Multiview camera	ABS TRC ESC	CMBS E-pretensioner	Collision safety body Seatbelt/child seat Airbag system Pop-up hood Active headrest	Emergency alert system Energy-sensitive door unlock system

Figure 1. Areas incorporating safety technologies

7.1.1 Active safety

As of 2013, there are approximately 600,000 automobile accidents in Japan per year, and there is ongoing research and development and efforts to spread active safety technologies for preventing automobile accidents through the use of electronics and control technologies.

(1) Visibility enhancement technologies

Today we are seeing the practical use of high-luminosity discharge and LED headlights, which can improve forward visibility at sunset, at nighttime, and during inclement weather. There has also been increased implementation of adaptive front-lighting systems, which measure steering angle and vehicle speed to calculate the forward path of automobiles through turns in order to control the reflective mirrors of the headlight units, orienting them to better illuminate the path of travel.

Figure 2. Intelligent night vision system enhancing visibility of pedestrians[1)]

Indirect visibility is being improved as well. Installation of multiple cameras onto the car body allows display on monitors of traffic lanes at intersections with poor visibility, displays of the vehicle size superimposed on a rear-view image of the car when it is in reverse, and displays of the full area around the vehicle. Such fusions of video display with graphic image processing technologies allows for visibility enhancements of what is happening all around the vehicle.

Night vision systems to alert drivers of obstacles are also being developed (Fig. 2[1)]). Shining infrared light in the direction of travel during nighttime driving allows use of infrared cameras that can visualize and emphasize pedestrians or road conditions that would otherwise be difficult for the driver to see with the naked eye.

(2) Driving workload reduction technologies

While traditional cruise control systems maintain a constant speed on highways, adaptive cruise control (ACC) systems monitor conditions in front of the car by using millimeter-wave radar and stereographic cameras, and automatically adjust travelling speed to maintain a constant distance from other vehicles. ACC systems can be used not only to maintain speed on high-speed roadways, but also to provide proximity alerts and collision prevention in heavy traffic conditions on general use roads. Low-speed ACC systems in particular can be used in conjunction with collision mitigation braking systems to avoid or reduce low-speed collisions, and are looked to as a way of reducing the number of accidents at intersections, which account for the majority of traffic accidents.

Lane departure warning systems that use cameras and lane confirmation technologies are practical. In addition, intelligent driver assistance systems are being combined with car navigation systems. These can be used, for example, to notify or warn drivers of upcoming intersections at which a full stop is required.

(3) Vehicle dynamic performance technologies

When turning a steering wheel, if tire rotation is locked, then sufficient lateral force cannot be generated for yaw motion of the vehicle. For that reason almost all cars today have anti-lock braking systems (ABS) as standard equipment. ABS constantly monitors wheel rotation, and in cases where slippery road surfaces cause wheel locking during braking, briefly releases brake pressure to resolve the lock. By then raising brake pressure in a manner that prevents re-locking, braking can be performed in a manner that still permits steering wheel operation.

Electronic stability control systems have been required as a standard feature on all new automobiles since October 2012. These combine ABS with traction control systems, which prevent tire spinning during starts and acceleration, to provide active unified control of the force generated by each tire and thus prevent or reduce wobble and sideslip of vehicles. Integrating such systems with electronic power steering and others has also been promoted, which allows for overall improvements to vehicle dynamic performance, realizing better danger and accident avoidance in emergencies.

7.1.2 Passive safety

This section introduces technologies for minimizing damage to humans in the event of an accident.

(1) Collision damage mitigation technologies

The impact that is transmitted to occupants in a collision depends on the vehicle's momentum, which is the product of its mass and velocity. In the case of an extremely rigid vehicle body, the impact is immediately transmitted to the occupants, increasing the likelihood of serious injury. Engine compartments therefore have a "crumple zone" designed to deform and thereby absorb rather than transmit energy, reducing the amount passed on to occupants. In current methods of frame design, the amount of frame deformation in the time domain is calculated at the design stage, and design proceeds to ensure that the impact force delivered to occupants does not exceed a given critical danger value.

In vehicle-on-vehicle collisions, differences in the form of the colliding automobiles can result in impacts at different frame locations, sometimes significantly lowering the functioning of the crumple zone. The frames of light motor vehicles and standard class passenger cars are thus now designed to retain some degree of compatibility so that in the event of a collision, the frame of each can function as designed (Fig. 3[2)]).

Another recent technology for reducing the impact to passengers during a collision is emergency locking retractor seatbelts equipped with pretensioners and load limiters. When a collision is detected these seatbelts instantly retract any slack, and then

Figure 3. Schematic diagram of crash-compatible car bodies[2)]

the belt is fed out when a certain load is exceeded. Doing so can reduce injury to the chest.

Supplemental restraint system airbags have become standard equipment for both driver and passenger seats. In recent models collisions can be detected approximately 0.015 seconds after they occur. By varying the airbag inflation rate according to the speed of impact and constantly changing the airbag volume, passengers with various body types can be better protected. Side impact airbags that inflate in a curtain shape are also being increasingly deployed, and are effective toward reducing head and neck injuries.

(2) Pedestrian injury mitigation technologies

As a way of reducing injury to pedestrians in the event of a collision, automobile bumpers, fenders, and hoods are now being designed with space beneath them and are being manufactured with easily dented materials. Hood hinges are also being constructed so that when a strong force is applied to them they fold so as to absorb energy. Protrusions are being eliminated from car bodies to the extents possible to remove locations where a human body might get caught in a collision; this is one of the reasons why retractable headlights that pop up only when in use are no longer seen. Yet another safety feature is hoods that pop up at the moment a collision is detected, to produce a larger space beneath them.

7.2 Commercial vehicles

The forms of buses and large trucks are inherently different from those of passenger vehicles, due to the need to retain space for passengers and cargo. These vehicles are also operated in different ways, and so have unique safety features according to their characteristics.

Such vehicles are large, and truck beds or loaded cargo can create blind spots from the driver's seat, particularly to the rear and sides.[3)] These blind spots are being eliminated through the use of multiple mirrors as well as rear-facing cameras and sonar equipment that allow for confirmation of the status of areas of poor visibility. In recent years there have been trials of making the lower portion of passenger side door panel transparent, to improve side visibility.

Commercial vehicles remain in continuous operation for longer periods than do passenger vehicles, so equipment for monitoring driver attention is in practical use. As an example, certain systems use cameras to monitor the direction that drivers are facing and the status of their eyes, to ensure they are paying attention. Another system uses fuzzy logic to analyze the first 15 minutes of driving behavior, and from this can detect declines in driver attention from steering wheel operations and the like. In both cases, when driver inattention is detected a warning is sounded and displayed. An alarm can also be sounded when driver inattention is accompanied by weaving or failure to maintain lanes, and when this happens multiple times in sequence accidents can be prevented by decreasing the timing before which collision damage mitigation braking is applied.[4)]

With regards to vehicle dynamic performance, heavy-duty vehicles generally weigh more than passenger vehicles, and large loads on trucks can raise their center of gravity. This makes it easier for trucks to roll over or spin out in turns, leading to accidents. Today, in order to reduce such accidents, electronic stability control systems are being used in heavy-duty vehicles, just like in passenger vehicles.

Approximately 50% of accidents involving commercial trucks are rear-end collisions, and on highways the ratio reaches as high as 72%.[5] In an effort to reduce these accidents, implementation of collision mitigation braking systems is beginning to become mandatory for trucks. Trucks also tend to have a large clearance between their body and the road, leading to a submarine phenomenon at the time of collision with other categories of vehicles. Vehicle under-run protection devices are therefore currently mandatory, increasing compatibility with other automobiles as in the case of passenger vehicles.

In the future, we can expect to see more commercial vehicles adopting technologies from the ITS field, such as spacing maintenance systems (electronic horn system) using road-to-vehicle and vehicle-to-vehicle communications devices for comprehending conditions in the vicinity of operation. Also, these are expected to reduce the number of accidents involving other vehicles and to allow the formation of lines of trucks that automatically follow leader trucks, reducing fatigue in long-distance truck drivers.

7.3 Motorcycles

Motorcycles have two wheels, one in front of the other, and so must maintain balance at all times while in operation. Control operations are also more direct, such as by the rider directly changing steering angle or leaning the vehicle while in turns. There are some advanced systems that, for example, adjust engine output according to the vehicle attitude to prevent rear-tire skidding, but direct intervention through electronic stability control, such as that used in four-wheeled automobiles, is difficult.

One safety feature that accommodates these differences and is currently in practical use is an ABS system that uses electronic controls to link the front and rear wheel brakes. Motorcycles have a higher center of gravity than four-wheeled vehicles due to their shorter wheelbase and higher passenger-to-vehicle mass ratio. This results in a higher load transfer from the rear wheel to the front wheel under braking. Fig. 4 shows the resulting ideal braking force distribution curve for a motorcycle. Unlike the case in four-wheeled vehicles, when a motorcyclist applies sudden braking in excess of 0.5 G, the braking force on the front wheel must be increased and that on the rear wheel decreased. Attempts to apply single-input braking similar to that in

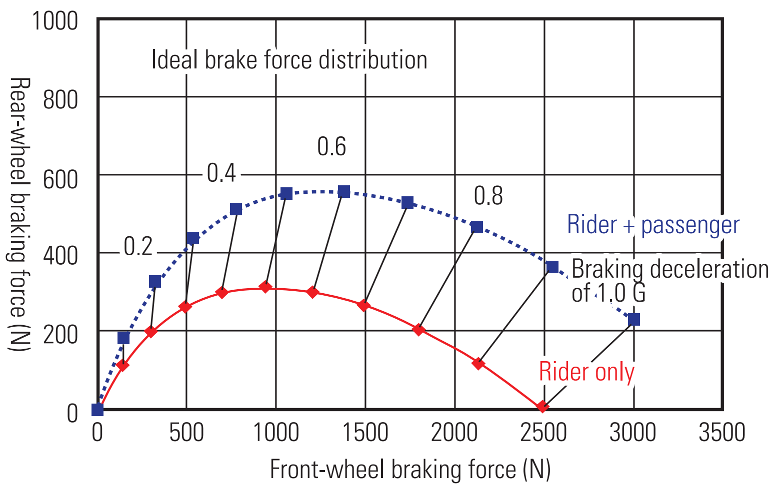


Figure 4. Ideal brake force distribution for motorcycle

automobiles result in complex apparatuses for rear-brake fluid pressure reduction, which is impractical for practical application given the motorcycle's limited mounting space. Most motorcycles thus have separate front and rear brake systems that riders themselves must operate independently in attempts to reproduce the ideal braking force distribution curve.

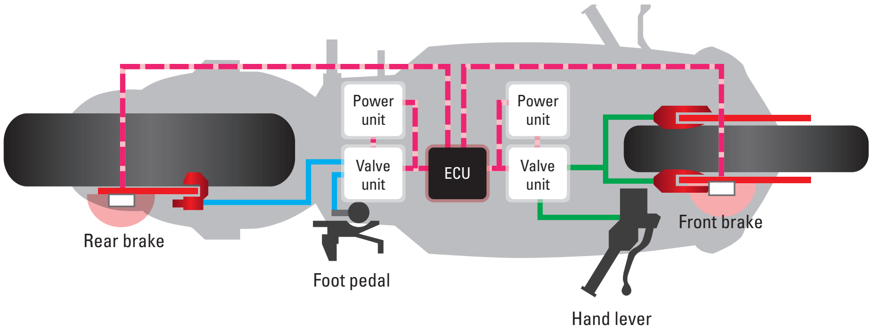


Figure 5. Diagram of electronically controlled combined ABS[6)]

Electronic control of front and rear brakes coordinated through a by-wire can convert rider input to electronic signals, allowing computers to control both braking and the fine-grained activation of the ABS. This electronic control allows elimination of the ABS-dedicated equipment that was previously mounted on moving parts of the suspension, allowing use of standard parts.[6)]

Another new technology is dual-clutch transmissions which reduce the shock caused by gear changes. This allows riders a larger margin of operation, and is expected to reduce the risk of accidents.[7)]

Regarding passive safety, due to motorcycles' riding form and much smaller machine size, it is difficult to provide crumple zones like those seen in four-wheeled vehicles. However, through development of the ASV, some larger motorcycles now feature airbags. These airbags feature forms, sizes, and inflation methods particular to motorcycles, designed to accommodate the non-restrained seating of a rider.[8)]

In recent years there riding jackets equipped with internally stored airbags have also been developed. These airbags automatically inflate when the rider becomes separated from the motorcycle due to a collision or rollover.

Motorcyclists on city streets frequently travel between lanes or along road shoulders to avoid traffic. As ITS becomes more widespread, road-to-vehicle and vehicle-to-vehicle communications devices like those described for automobiles are expected to decrease the number of accidents

Advanced Safety Vehicle and Driving Safety Support Systems (ASV/DSSS) to prevent left-turn accidents

[Purpose] To prevent left-turn accidents, information on hard-to-see vehicles is provided some distance back during left turns at an intersection with traffic signals.

[Expected benefits] Reduction in the number of left-turn accidents (accident prevention through provision of information regarding blind spot)

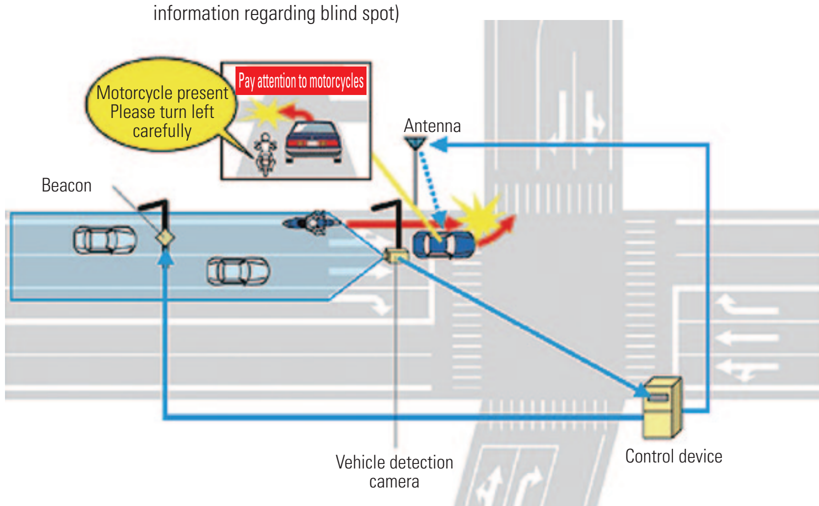


Figure 6. Vehicle-infrastructure cooperation under the intelligent transport system[9)]

at intersections or involving cars turning in front of motorcycles, as such devices can alert other vehicles to their presence (Fig. 6[9)]).

7.4 Other safety technologies

There have also been significant changes in tire technology. Run-flat tires (Fig. 7) have reinforced sidewalls that allow travel for some distance following a puncture. This allows vehicles to be operated without carrying a spare, reducing vehicle weight and thus fuel consumption.

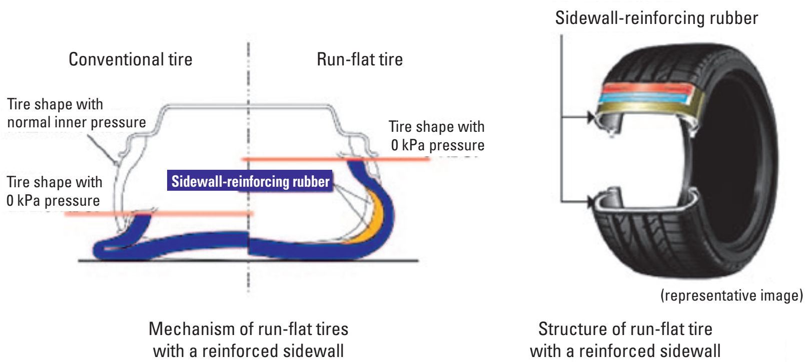


Figure 7. Structure of a run-flat tire[10)]

Vehicle body component materials too are changing. While their use remains limited at present, we are starting to see the use of carbon fiber-reinforced plastic, in addition to the traditional ultra-tensile steel in consumer vehicles. This is expected to further reduce vehicle weight, improving running characteristics and decreasing fuel consumption. As body designs advance, assuming the increased use of such composite materials, freedom of design will allow increased safety over current mainstream body shapes.

Electric and hybrid vehicles are increasingly popular due to their environmentally friendly nature, but vehicles operating under electric power make much less sound than do those with an engine drive. This can result in pedestrians being unaware of their presence, increasing their involvement in accidents. Some such vehicles now issue an electronic sound when operating in electric mode, alerting those around them to their presence. Electric vehicles also contain high voltage components, so designs are now taking this in consideration to prevent accidental electrocution in the event of accidents.

As society continues to age, the rise of a new category of vehicles is becoming apparent: ultra-compact mobility devices with very small vehicle footprints and high maneuverability (Fig. 8[11)]). These vehicles generally

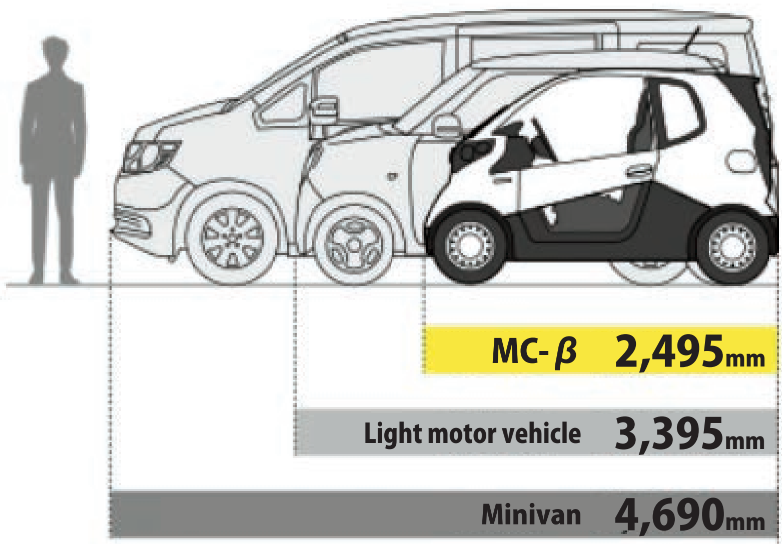


Figure 8. Size comparison of ultra-compact mobility devices[11)]

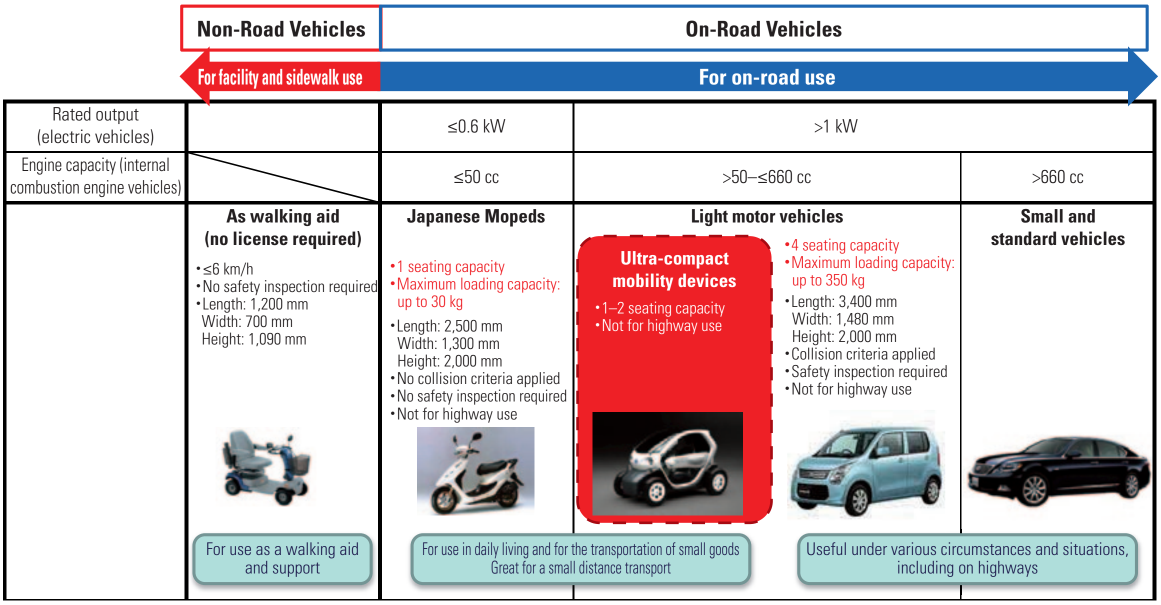


Figure 9. Ultra-compact mobility devices in comparison with conventional vehicles in Japan[12)]

allow only one or two occupants, and consume only about a sixth the energy of a standard vehicle (or about half that of an electric vehicle). They are generally intended for local travel near the home, excursions at tourist destinations or commercial areas, and small-scale delivery operations, but as they become more popular, more of these vehicles will likely be mixed in with general traffic, and there will be a need to confirm that they are differentiated and supplied with sufficient running space (Fig. 9[12)]).

As with motorcycles, these vehicles are very small, making it difficult to design them with crumple zones. However, as they become more prevalent there will be an increasing need for developing compact, cost-effective collision prevention devices to reduce the number of accidents that they become involved in.

References

1) Honda Motor Co., Ltd. 2004. “Honda Develops World’s First Intelligent Night Vision System Able to Detect Pedestrians and Provide Driver Cautions: Available on Legend model to be released in Fall 2004.” *Honda Worldwide*, August 24. Accessed December 10, 2014. http://world.honda.com/news/2004/4040824_01/video/index.html.
2) Honda Motor Co., Ltd. 2014. “The crash-compatibility body: increasing overall safety for everyone on the road.” *Honda Worldwide*. Accessed December 10, 2014. http://world.honda.com/automobile-technology/compatibility/
3) Japan Safe Driving Center. 2007. *Ogata kamotsusha no anzen unten* [Safe driving of large freight vehicles]. Accessed December 10, 2014. http://www.jsdc.or.jp/search/pdf/all/h18_3.pdf. (in Japanese)
4) Mitsubishi Fuso Truck and Bus Corporation. 2008. “Dai 58 kai jidosha gijutsu kai sho de unten chui ryoku monita (MDAS-III) ga gijutsu kaihatsu sho o jusho” [Mitsubishi’s Driver’s Attention monitoring system won the Technology Development Award at the 58th Society of Automotive Engineers of Japan, Inc. award contest]. Accessed December 10, 2014. http://www.mitsubishi-fuso.com/jp/news/news_content/080424/080424.html. (in Japanese)
5) Japan Trucking Association. 2014. *Jigyo yo kamotsu jidosha no kotsu jiko no keiko to jiko jirei* [Trends and examples of accidents involving large commercial freight vehicles]. Accessed December 10, 2014. http://www.jta.or.jp/member/pf_kotsuanzen/jikojirei.pdf. (in Japanese)
6) Honda Motor Co., Ltd. 2014. “Taking super sport riding to a new level-world’s first Electronically Controlled Combined ABS for super sport bikes.” *Honda Worldwide*. Accessed December 10, 2014. http://world.honda.com/motorcycle-picturebook/eCBS/.

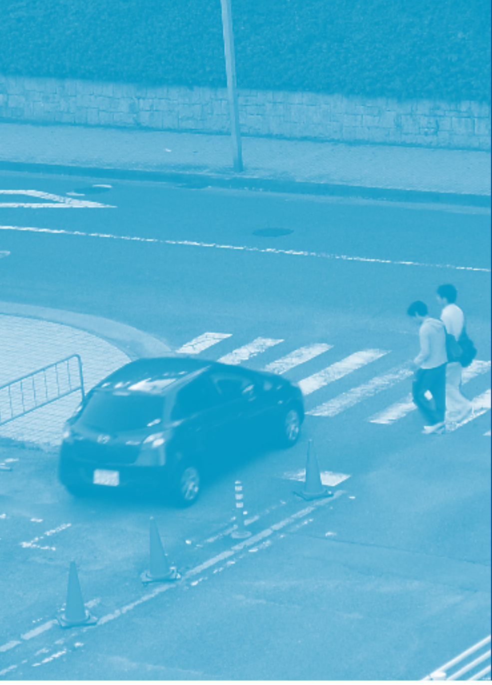
7) Honda Motor Co., Ltd. 2014. "Enjoy the performance of a manual transmission with the convenience of an automatic. Honda introduces the world's first dual-clutch transmission for use in a motorcycle." *Honda Worldwide*. Accessed December 10, 2014. http://world.honda.com/motorcycle-picturebook/DCT/.
8) Honda Motor Co., Ltd. 2014. "The world's first production motorcycle airbag system, designed to help lessen the severity of injuries to the rider in a frontal collision." *Honda Worldwide*. Accessed December 10, 2014. http://world.honda.com/motorcycle-picturebook/Airbag/.
9) Honda Motor Co., Ltd. 2008. "Honda Begins Testing of Advanced Safety Vehicles and Driving Safety Support Systems on Public Roadways: Honda Cooperating on Development of Driving Safety Support Systems Using Inter-Vehicle and Road-to-Vehicle Communications to Help Reduce Traffic Accidents." *Honda Worldwide*, March 24. Accessed December 10, 2014. http://world.honda.com/news/2008/4080324Advanced-Safety-Vehicles/.
10) Bridgestone Corporation. 2014. "Key components of Run-Flat Technology tires." *RFT: BRIDGSTONE Run-Flat Technology*. Accessed December 10, 2014. http://www.bridgestone.com/sc/runflat-system/technology/index.html.
11) Honda Motor Co., Ltd. 2013. "Honda Unveils MC-β, New Micro-sized EV: Field tests will begin in Kumamoto, Saitama and Miyakojima." *Honda Worldwide*, November 19. Accessed December 10, 2014. http://world.honda.com/news/2013/4131119MC-Micro-sized-EV/index.html.
12) Ministry of Land, Infrastructure, Transport and Tourism. 2013. "Cho kogata mobiritei no donyu sokushin" [Promotion of ultra-compact mobility vehicles]. Accessed December 10, 2014. http://www.mlit.go.jp/common/000986236.pdf. (in Japanese)

Recommended Reading

1) Society of Automotive Engineers of Japan, Inc., ed. 2009. *Jidosha no hyakka jiten* [Encyclopedia of automobiles]. Maruzen Co., Ltd. (in Japanese)
2) Ministry of Land, Infrastructure, Transport and Tourism. 2008. "Senshin anzen jidosha ni kansuru kenkyu seika hokokusho: ASV (Advanced Safety Vehicle) no kenkyu seika to kongo no gijutsu houshin" [Report on research results regarding Advanced Safety Vehicle: Results of research on ASV and future technological guidelines]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv1report.pdf. (in Japanese)
3) Ministry of Land, Infrastructure, Transport and Tourism. 2001. "Senshin anzen jidosha (ASV) suishin keikaku (dai 2 ki) ni kansuru hokokusho" [Report on promotion plan for advanced safety vehicles (2nd stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv2report.pdf. (in Japanese)
4) Ministry of Land, Infrastructure, Transport and Tourism. 2006. "Senshin anzen jidosha (ASV) suishin keikaku hokokusho: dai 3 ki ASV keikaku ni okeru katsudo seika ni tsuite" [Report on the promotion plan for advanced safety vehicles: results of ASV promotion plan (3rd stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv3seikahoukokusyocorrection.pdf. (in Japanese)
5) Ministry of Land, Infrastructure, Transport and Tourism. 2011. "Senshin anzen jidosha (ASV) suishin keikaku hokokusho: dai 4 ki ASV keikaku ni okeru katsudo seika ni tsuite" [Report on the promotion plan for advanced safety vehicles: results of ASV promotion plan (4th stage)]. Accessed December 10, 2014. http://www.mlit.go.jp/jidosha/anzen/01asv/resourse/data/asv4pamphlet_seika.pdf. (in Japanese)

Practical application projects for reference

A study on the role and limitations of motorcycles as a means of urban transport in Southeast Asia: 156–159



Chapter 8

Traffic psychology

8.1 Perception and cognition of drivers

When operating a vehicle, drivers gather information from the surroundings based on their intended purpose and process the information accordingly to operate the steering, pedals, and switches. Although this appears to be a series of simple tasks, these actions involve various mental processes such as predicting changes in the surrounding environments, gathering information for subsequent actions, and detecting and handling dangerous situations. The process of gathering external information is defined as perception, and the process of understanding and handling the external information is defined as cognition. The perception and cognition of massive amounts of information is performed largely automatically and unconsciously, in accordance with complex rules and under strict time limits. These mental processes, which are performed without any errors, are critical for safe driving.

As in Figure 1, all human behaviors, not limited to driving, are represented in a schematic diagram.[1)] According to this model, human behaviors involve three levels of information processing (skill-, rule-, and knowledge-based) between the input of information and the output of action. The perceptual features of sensory information obtained via the sensory organs are analyzed to recognize the content of the information. If the content is already well-known, appropriate responses are elicited quickly at

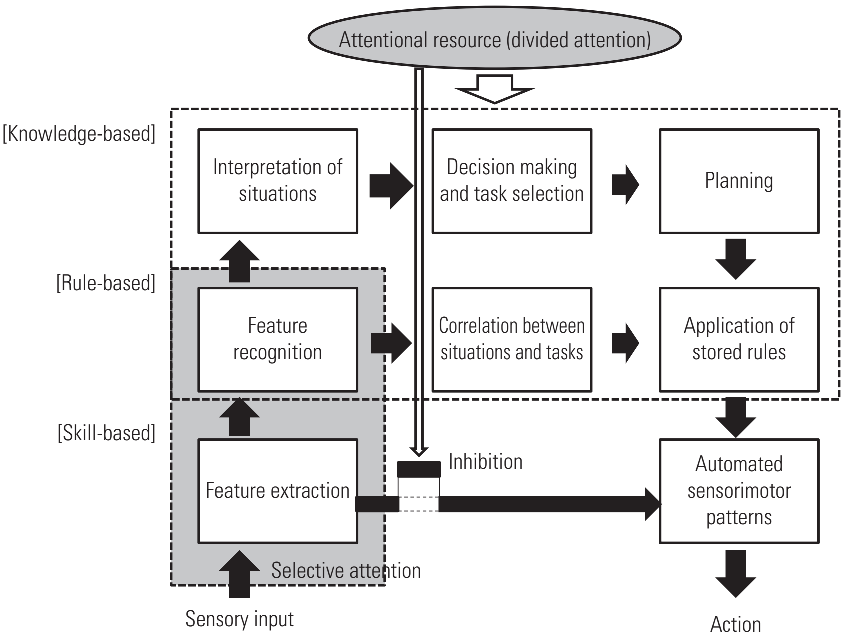


Figure 1. Three-level behavior control model based on Rasmussen's SRK model

the point of feature formation. This skill-based response is rapid and unconscious but is also fixed and inflexible. When it is necessary to behave in accord with informational content, rules for selecting a response are recalled in order to behave appropriately. Attention is not required when the behavior to be performed is simple and familiar, whereas a certain degree of attention is required when the behavior is unfamiliar. When the information is novel and totally unfamiliar, information processing is “knowledge-based,” which is a conscious process to interpret information and make behavioral decisions. A behavior at this level can be slowly but flexibly controlled, and requires sufficient attention.

Most basic driving operations, such as steering and pedal operation, are controlled at the skill-based level, while rule-based processing is required when drivers have to think about driving. For example, drivers have to behave at the knowledge-based level when they encounter an irregular road situation in which the road priority is unclear and when they have to make a route to the destination. In models of driver behavior, hierarchical concepts (operational, tactical, and strategic) have been used to explain driver behavior.[2)] In particular, the operational and tactical levels apparently correspond to the skill- and rule-based levels, respectively.

In addition, attention plays an important role in driving. Attention may be classified into selective attention for selectively gathering information and divided attention for working as mental energy to execute actions. The cognitive process in which these two processes are deeply involved is also shown in Figure 1.

8.2 Hazard perception

A hazard is a source of danger that may cause an accident, and hazard perception is defined as the detection of hazards and the recognition of their characteristics while operating a vehicle. Hazards are divided into overt hazards (e.g., visible pedestrians ahead) and latent hazards (e.g., unseen pedestrians in blind spots), and hazards need to be detected in a timely manner. Hazard perception may also be regarded as a situational awareness step required for securing safety.[3)]

When operating a vehicle, hazard perception relies for the most part on vision. To capture hazards by central vision, which is highly effective but limited to a narrow area, visual information must be obtained by looking at places where the presence of hazards is highly probable, while anticipating and paying careful attention to the appearance of hazards. Selection of visual information is strongly affected by drivers’ expectations and value judgments. If a driver has insufficient intention to detect hazards, “inattentional blindness” can occur, which is a phenomenon where visible objects are viewed but overlooked.[4)]

Drivers are also required to quickly determine which elements or situations are hazardous based on their experiences and knowledge. To do so, drivers must be able to store hazardous experiences, scan the contents quickly, and recall the experiences. Drivers gradually acquire hazard-related knowledge through driving experiences and develop a schema about hazards. Schemas are generated based on the past experiences of events, actions, and objects, and are constructed with a number of generalized concepts.[5] Behavior control by schemas is generally an unconscious and automatic process,[6] and schemas compensate for insufficient information by using default values.[5] Schemas are the basis for smooth human behavior. By constructing schemas, drivers can recognize scenes containing hazards more correctly and comprehensively, as shown by previous studies.[7, 8]

For preventing accident, it is extremely important to perform hazard perception effectively. Consequently, various hazard perception tests have been developed and incorporated into driver's license examinations in Western countries as well as in Japan.[9] In a typical hazard perception test, drivers observe a video of the view from the driver's seat and push a button as soon as they discover a hazard. Drivers' hazard perception ability is evaluated based on the time taken to detect and react to a hazard and the overall detection rate. In general, skilled drivers have short detection and reaction times and a high detection rate compared with novice drivers.[10, 11] Previous studies of eye movements during hazard perception testing suggest that the difference in reaction time between skilled and novice drivers is due to the difference in time taken to process and determine the degree of hazard rather than the difference in their respective abilities to detect hazards.[12, 13]

In addition, due to the increasing number of elderly drivers, research is currently underway to investigate age-related changes in hazard perception ability. While some studies have shown that hazard perception test scores are low among elderly drivers compared with younger drivers,[14, 15] other studies have revealed no age-related difference in hazard perception abilities.[16] Further studies are needed to clarify whether hazard perception test scores among elderly drivers are affected by a decline in visual function itself (e.g., a decline in contrast sensitivity); a reduction in the useful field of view, which is indicative of an overall decline in the mechanism of attention; or age-related modifications in the structure and mechanism of the schema that is the basis of hazard perception.

Educational and training programs are offered to improve hazard perception ability. One of the methods is to point out hazards hidden in still images and videos of traffic scenes. As mentioned earlier, hazard perception is based on a schema constructed with a variety of knowledge regarding dangers. To perform hazard perception effectively, drivers should not only memorize extensive knowledge about typical and individual hazards and immediately retrieve knowledge appropriate for a particular scene, but also generalize such knowledge to meet novel situations. Therefore, it is necessary to educate drivers and give them an understanding of the processes by which hazards cause accidents and the information that makes hazard detection easier, rather than simply teaching them how to respond to individual hazards. For example, driving schools in Japan already provide hazard perception training in the form of discussion-based training on hazard prediction and driving while predicting hazards. To improve hazard perception education, the incorporation of psychological approaches based on the perceptual and cognitive processes of hazard prediction into the content of driver's education should be considered.

8.3 Risk taking

In traffic psychology, the term "risk taking" has long been used as a concept associated with accidents based on the assumption that accidents are more likely caused by drivers with a tendency to act despite being aware of potential risks. In particular, risk taking is given as the reason for high accident rates among young drivers.

When individuals exhibit a tendency toward taking risks, they may behave in the same way but for different reasons; some enter risky situations without knowing what is dangerous, while others take risks despite being aware of the danger, for example to seek thrills. When drivers enter intersections against a red traffic signal, they may do so with or without being aware of the signal. From the perspective of individual traits, the former may have problems with hazard perception, while the latter may have behavioral problems, such as a risk-taking tendency.

Trimpop defines risk taking as all actions that are engaged at the time of perceiving elements of uncertainty or possibility of loss.[17)] Accordingly, almost all traffic behaviors involve risk taking due to the uncertainties associated with such behaviors compared with other ones in daily life.

Traffic behaviors reflect mental processes performed under extremely high time pressure, and their features affect risk-taking behaviors. Driving and traffic behaviors are characterized by the rapidity and continuity of the process between hazard or risk perception and risk taking via decision making.

As covered in the previous section, good hazard perception ability, for foreseeing and detecting in advance the objects or situations that may lead to accidents, is essential for safe driving. However, the risk of potential accidents linked to one's own driving is evaluated with respect to those hazards in a comprehensive manner. If one's driving skills are judged to be sufficient to handle driving challenges, then risks are evaluated as being low even though hazards are perceived correctly.

However, even when risks are evaluated to be high, if utility such as shortened time or increased admiration from others is judged more important, it is likely that the risks will be accepted and risk-taking behaviors will emerge. If gains are made by engaging in high-risk behaviors, the risks are rewarded, generating positive reinforcement. For example, if the time required to reach the destination is shortened by traveling at high speed, then the behavior is rewarded. In other words, driving behaviors are associated with gains due to stress release and rushed driving. This quality, where gains exert an effect on risk taking or risk avoidance behaviors, is called risk utility.

Human motivation involves various types of risk utility, such as releasing stress, violence, expressing independence, increasing arousal levels, increasing on-road travel efficiency (in a hurry to reach one's destination), rebelling against adult authorities, and receiving admiration from peers. Furthermore, compared with middle-aged individuals, young individuals tend to attach importance to appearance and style, but not safety features, when purchasing a car. These motivations often affect risk-avoidance behavior.

Particularly in recent years, sensation seeking has been attracting a lot of attention. According to Zuckerman, sensation seeking is defined as an individual trait that plays a role in seeking various, novel, complex, and intense sensations or experiences and for taking physical, social, legal, and financial risks to gain such experiences.[18)] According to this definition, sensation seeking is nothing but a motivation for taking risks.

As the knowledge of risk utility increases, it has become apparent that the improvement of risk perception alone is not enough to reduce the risk-taking tendency or increase the risk-avoidance tendency of drivers. To understand why drivers behave in certain ways, it is important not only to study the possibility of accidents as risk non-utility, but also to simultaneously take into account risk utilities, including sensation seeking and admiration of others.

Most active discussions regarding risk acceptance and avoidance in recent years are about the issues surrounding the theories of risk compensation and risk homeostasis. Risk compensation is a tendency of traffic participants to offset or reduce the merits of safety measures by engaging in risky behavior. For example, even when the safety of streets is improved, traffic participants may partly negate these safety benefits by behaving negatively, such as increasing the speed of the vehicle and failing to perform safety checks.

According to the theory of risk homeostasis proposed by Wilde,[19)] we as individuals set target risk levels for various activities and modify our behaviors to achieve or maintain these levels. As a result, the number of accidents will not be reduced unless safety measures are designed to decrease target risk levels, suggesting that behavior moves towards danger to the same extent as does the merit generated by the safety measure. However, risk homeostasis theory is often criticized because it is unlikely that individual drivers can estimate safety merits accurately.

8.4 Behavior and education of elderly drivers

As it is a challenge associated with an aging society, the prevention of accidents among elderly drivers is discussed actively. However, careful discussions are needed to clarify whether elderly drivers are indeed high risk compared with younger drivers, because even with some form of functional decline, elderly drivers are able to reduce the actual risk of accidents by avoiding high-risk driving (driving at night or in rain) or driving carefully, for example, by slowing down. Such "compensatory driving" behaviors among many elderly drivers have already been demonstrated by many studies.

However, research has also revealed that the accident rate for a given driving distance is higher among elderly drivers compared with other age groups, except for young adults. According to Fujita, the number of fatal accidents and traffic accidents among elderly drivers is respectively 3 and 1.5 times that of other age groups excepting young adults.[20)]

Poor driving performance is thought to be the reason for high accident rates among elderly drivers. Using behavioral indicators (safety checking behavior and speeding behavior) and driving assessment indicators used by instructors to evaluate the driving performance of elderly drivers, Renge et al. revealed that the number of times elderly drivers looked to the right and left for oncoming traffic was fewer than that of drivers in other age groups[14)] (Fig. 2). Although no age-related difference was observed in the speed during routine driving, at the intersections with a stop sign, elderly drivers drove faster at intersections with poor visibility or stop signs, compared with other age groups, indicating that many elderly drivers fail to perform one of the safe driving basics: stopping to check traffic.

However, as mentioned earlier, many studies have reported that elderly drivers counterbalance functional decline and the deterioration of their driving performance with compensatory driving behavior. Matsuura, Ishida, and Mori developed the safe driving workbook, which includes dangerous driving scales and compensatory driving scales to test their hypothesis that elderly drivers engage in compensatory driving behaviors to avoid dangerous situations upon realizing potentially dangerous driving performance due to functional decline.[21] Their study revealed that dangerous driving and compensatory driving scores increased with age. Furthermore, as the scores for dangerous driving increased, elderly drivers were involved in more accidents and committed more violations, and their driving behaviors were rated lower by instructors.

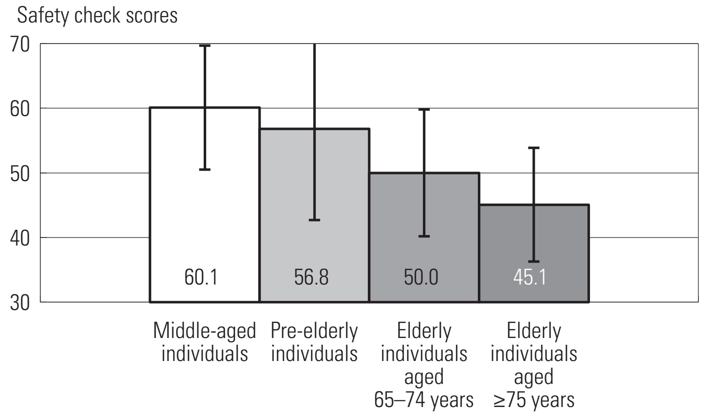


Figure 2. Safety check scores by age group

A previous study performed at a driving school has shown the effectiveness of a program that educates elderly drivers how to comply with stop signs and verify traffic safety.[22] The educational program was developed because elderly drivers are generally not good at stopping at stop signs or checking traffic safety. In this program, using the behavior check and feedback approach, (1) elderly drivers drove through the predetermined course at the school using one of the school cars, and their performance was videotaped (performance-based diagnosis), and (2) elderly drivers evaluated their driving behavior on the video and received feedback from the instructors.

After converting this educational method into a practical coaching method, developing an educational manual for instructors, and training them, Renge et al. asked appropriate questions and provided feedback to cause program participants to recognize their own problems.[23] In the program, participants slowed down at intersections and increased their number of traffic safety checking steps compared with non-participants (Fig. 3). The efficacy weakened but persisted over one month after the program.

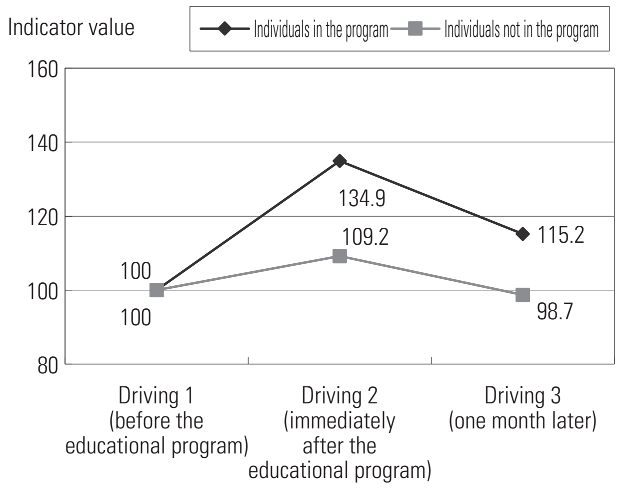


Figure 3. Educational efficacy in terms of total number of safety checks

Although it is sometimes questioned whether educational programs for elderly individuals are effective, a certain level of efficacy can be expected with the use of this method, where program participants check their own driving performance and receive appropriate feedback.

8.5 Behavior and education of bicycle users

The rate of bicycle-related accidents is high among children and elderly individuals, and failing to stop at stop signs, ignoring traffic signals, traveling the wrong way, and crossing streets inappropriately have been indicated as potential reasons. Furthermore, analysis performed by the International Association of Traffic and Safety Sciences (IATSS) in 1995 and adjusted for the number of licensed drivers and for traveling time has shown that elderly individuals with no driver's license have a high rate of accident.[24) Although a similar trend is observed among young and middle-aged individuals, the problem is more serious for elderly individuals because of the low proportion of licensed drivers in this group.

In 2012, the IATSS also conducted a study using the driving lanes at a driving school to investigate behavioral characteristics such as stopping and checking the safety at intersections.[25) The study evaluated where bicycles traveled in their lane and safety checking behavior (how many times bicycle users looked to the right and left at intersections, and how thoroughly they did so).

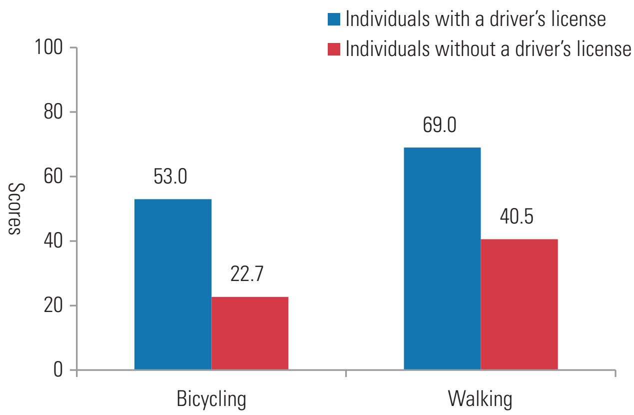


Figure 4. Effect of obtaining a driver's license on total safety check scores for bicycling and walking

Figure 4 shows the effect of obtaining a driver's license, which includes the benefits of driving experience and drivers' education. The results indicate that higher safety check scores at intersections were obtained by bicycle users with a driver's license than by those without. The former also scored higher for location of their bicycle on the road, showing that they choose to travel closer to the roadside than the latter did.

However, bicycle users without a driver's license set low standards for safety checking, the location of their bicycle, and driving behavior, thereby showing high-risk behavior, when riding a bicycle compared with when walking. We interpreted this to mean that elderly bicycle users who have a driver's license can readily engage in appropriate risk avoidance behavior, owing to driving skills and knowledge previously acquired at driving school or through their own driving experiences. The early establishment of educational programs for bicycle users that are equivalent to driver's education programs may reduce accidents among bicycle users who do not have a driver's license, and therefore, proactive educational programs should be provided in cooperation with schools and local traffic safety associations.

Using an observational and coaching method, Ogawa developed a bicycle education program for high school students based on his hypothesis that a lack of awareness of one's behavior and role as a cyclist is a factor causing unsafe behaviors.[26) By applying the basic principles of coaching, observation of others was performed in several steps such as group discussions, video viewing, and bicycling simulation. Before and after the educational program, high school students created 20 self-awareness sentences starting with "I" using the 20-responses technique. Comparison of the sentences revealed that although the students provided general bicycling-related descriptions before the program, they increased both the number of statements and the descriptions about proactively securing safety, especially the safety-checking category, after the program. Such bicycling education programs that enhance self-awareness should be promoted because they are suited for and benefit adolescent individuals who are transitioning into adulthood, and provide lifelong benefits.

References

1) Shinohara, Kazumitsu. 2011. "Chui to hyuman era: Kotsu anzen to chui mondai o chushin toshite" [Attention and human error: On traffic safety and attention problem]. In *Theories and Applications of Cognitive Psychology 4: Attention and Safety*, edited by Etsuko Harada, and Kazumitsu Shinohara, 186–208. Kitaohji Publishing. (in Japanese)
2) Shinar, D. 2007. *Traffic safety and human behavior*. Elsevier.
3) Horswill, M. S., and F. P. McKenna. 2004. "A cognitive approach to situation awareness." In *A cognitive approach to situation awareness: theory and application*, edited by Banbury, S., and S. Tremblay. Ashgate publishing.
4) Chabris, C., and D. Simons. 2010. *The invisible gorilla: and other ways our intuitions deceive us*. HarperCollins Publishers.
5) Shinohara, Kazumitsu. 2013. "Ninchi to hyuman era" [Cognition and human error]. In *Human Factors Psychology for a New Era of Safety and Comfort*, edited by Kazumitsu Shinohara, and Takahiro Nakamura, 41–59.Yuhikaku Publishing. (in Japanese)
6) Harada, Etsuko, and Takatsune Kumada, Kazumitsu Shinohara, eds. 2013. "Chui to suikou kinou" [Attention and executive function]. In *The handbook of cognitive psychology*, edited by The Japanese Society of Cognitive Psychology, 94–95. Yuhikaku Publishing. (in Japanese)
7) Benda, H. V., and C. G. Hoyos. 1983. "Estimating hazards in traffic situations." *Accident Analysis and Prevention* Vol. 15: 1–9.
8) Borowsky, A., T. Oron-Gilad, and Y. Parmet. 2009. "Age and skill differences in classifying hazardous traffic scenes." *Transportation Research Part F: Traffic Psychology and Behaviour* Vol. 12: 277–287.
9) Nagayama, Yasuhisa. 2009. *Kanrisha no tameno kiken yosoku unten kyoiku: nichi, bei, o no kikenyosoku kyoiku to kyozai, tesuto mondai* [Driver's risk prediction education for instructors: The comparison of materials and tests for the risk prediction education among Japan, the United States, and Europe]. Kigyo Kaihatsu Center. (in Japanese)
10) Scialfa, C. T., M. C. Deschênes, J. Ference, J. Boone, M. S. Horswill, and M. Wetton. 2011. "A hazard perception test for novice drivers." *Accident Analysis and Prevention* Vol. 43: 204–208.
11) Borowsky, A., D. Shinar, and T. Oron-Gilad. 2010. "Age, skill, and hazard perception in driving." *Accident Analysis and Prevention* Vol. 42: 1240–1249.
12) Huestegge, L., E. M. Skottke, S. Anders, J. Müsseler, and G. Debus. 2010. "The development of hazard perception: Dissociation of visual orientation and hazard processing." *Transportation Research Part F: Traffic Psychology and Behaviour* Vol. 13: 1–8.
13) Wetton, M. A., M. S. Horswill, C. Hatherly, J. M. Wood, N. A. Pachana, and K. J. Anstey. 2010. "The development and validation of two complementary measures of drivers' hazard perception ability." *Accident Analysis and Prevention* Vol. 42: 1232–1239.
14) Renge, Kazumi, Tomikazu Ishibashi, Masaaki Oiri, Hiro Ota, Shigeyuki Tsunenari, and Marehiro Mukai. 2003. "Korei doraiba no unten pafomansu to hazado chikaku" [Driving performance and hazard perception of elderly drivers]. *Japanese Journal of Applied Psychology* Vol. 29, No. 1: 1–16. (in Japanese)
15) Renge, Kazumi, Masahiro Tada, and Marehiro Mukai. 2014. "Korei doraiba to chunen doraiba no risuku tekingu kodo ni kansuru jisshoteki kenkyu" [Empirical study on the risk taking behavior by elderly and middle-aged drivers]. *Japanese Journal of Applied Psychology* Vol. 39, No. 3: 182–196. (in Japanese)
16) Underwood, G., N. Phelps, C. Wright, E. van Loon, and A. Galpin. 2005. "Eye fixation scanpaths of younger and older drivers in a hazard perception task." *Ophthalmic & Physiological Optics: The Journal of the British College of Ophthalmic Opticians (Optometrists)* Vol. 25: 346–356.
17) Trimpop, R. M. 1994. *The psychology of risk taking behavior*. North-Holland.
18) Zuckerman, M. 1994. *Behavioral expressions and biosocial bases sensation seeking*. Cambridge University Press.
19) Wilde, G. J. S. 2001. *Target risk 2: a new psychology of safety and health*. PDE Publications.

20) Fujita, Goro. 1996. “Kotsujiko ritsu, kikenbakuro do oyobi untenkodo no nenrei ni yoru chigai” [Difference in the ratio of traffic accidents, the degree of danger exposure, and driving behaviors based on age]. *Reports of the Scientific Police Research Institute. Research on traffic safety and regulation* Vol. 37, No. 2: 48–57. (in Japanese)
21) Matsuura, Tsuneo, Toshiro Ishida, and Nobuaki Mori. 2008. *Korei doraiba no tameno anzen unten wakubukku* [The Safe Driving Workbook for elderly drivers]. Kigyo Kaihatsu Center. (in Japanese)
22) International Association of Traffic and Safety Sciences. 2004. *Korei doraiba eno kyoiku puroguramu to shien shisutemu no kaihatsu: heisei 15 nendo kenkyu chosa hokokusho* [Development of educational programs and a support system for elderly drivers: research report 2003]. International Association of Traffic and Safety Sciences. (in Japanese)
23) Renge, Kazumi, Hiro Ota, Marehiro Mukai, and Kazuhisa Ogawa. 2010. “Kochingu ho o mochiita korei doraiba eno kyoiku puroguramu no koka” [The effectiveness of educational programs for elderly drivers using a coaching method]. *Japanese Journal of Traffic Psychology* Vol. 26, No. 1: 1–13. (in Japanese)
24) International Association of Traffic and Safety Sciences. 1995. *Korei hokosha, jitensha joyosha no anzen ni taisuru unten-keiken no koka ni kansuru chosa kenkyu: heisei 6 nen kenkyu chosa hokokusho* [Research study on the effectiveness of driving experience of elderly pedestrians, cyclists, and drivers against safety: research report 1994]. (in Japanese)
25) International Association of Traffic and Safety Sciences. 2012. *Kodomo kara koreisha madeno jitensha riyosha no shinri kodo tokusei o fumaeta anzen taisaku no kenkyu (III): kenkyu chosa purojekuto hokokusho* [Study of safety measures based on the psychological and behavioral characteristics of cyclists from children to the elderly: a report of research project]. (in Japanese)
26) Ogawa, Kazuhisa. 2014. “Method Development for Safety Education Based on Students’ Self-Understanding.” *Memoirs of the Tohoku Institute of Technology: Ser. II: Humanities and Social Sciences* Vol. 34: 1–9. (in Japanese)

Recommended Reading

1) Wickens, C. D., and J. S. McCarley. 2008. *Applied attention theory*. CRC Press.
2) McKenna, F. P., and M.S. Horswill. 1999. “Hazard perception and its relevance for driver licensing.” *IATSS Research* Vol. 23: 36–41.
3) Endsley, M.R. 2000. “Theoretical underpinnings of situation awareness: a critical review.” In *Situation awareness analysis and measurement*, edited by M. R. Endsley, and D. J. Garland, 3–28. Lawrence Erlbaum Associates.
4) Marottoli, R.A., and E. D. Richardson. 1998. “Confidence in, and self-rating of, driving ability among older drivers.” *Accident Analysis and Perception* Vol. 30: 331–336.
5) Marottoli, R. A., E. D. Richardson, M. H. Stowe, E. G. Miller, L. M. Brass, L. M. Cooney Jr., and M. E. Tinetti. 1998. “Development of a test battery to identify older drivers at risk for self-reported adverse driving events.” *Journal of American Geriatrics Society* Vol. 46, No. 5: 562–568.
6) Matsuura, T. 2011. “Older drivers’ risky and compensatory driving: Development of a safe driving workbook for older drivers.” In *Traffic Psychology: An International Perspective*, edited by D. Hennessy, 87–113. Nova Science Publishers.
7) Oxley, J., B. Fildes, B. Corben, and J. Langford. 2006. “Intersection design for older drivers.” *Transportation Research Part F: Traffic Psychology and Behaviour* Vol. 9: 335–346.
8) Renge, K. 1998. “Drivers’ hazard and risk perception, confidence in safe driving, and choice of speed.” *IATSS Research* Vol. 22, No. 103-110.

Practical application projects for reference

Identification of brain regions associated with the central and peripheral visual field and applications for improving traffic safety: 164–167
An educational program for better control of emotions while driving: 168–171
A study on safety measures considering the psychological behavior characteristics of cyclists, from adolescents to the elderly: 172–175

Chapter 9
Traffic safety and medicine

9.1 Traffic accident casualty statistics

Traffic accident casualty statistics issued by the Japanese National Police Agency (NPA) are for on-road accidents as defined by the Road Traffic Act that resulted in fatality within 24 h of the accident. This statistic is the conventional reference when discussing traffic accident fatalities. Beginning in 1993, to better grasp the number of deaths occurring after that 24-h window and to allow for easier international comparisons, separate statistics that additionally include deaths occurring between 24 h and 30 days following an accident have also been calculated. NPA statistics for injury from traffic accidents classify injuries requiring treatment for less than 30 days as minor injuries, and those requiring 30 days or more of treatment as serious injuries. General injury statistics report a combination of both minor and serious injuries. In contrast, demographic statistics tally all persons dying within 1 year of a traffic accident, regardless of the site of the accident. Note that regardless of the period following the accident, medically speaking, all deaths due to involvement in modes of transportation are considered traffic accident deaths.

Nationwide statistics for 24-h traffic fatalities since 1989 peaked at 11,452 in 1992, and then fell for 13 consecutive years to 9,943 fatalities in 1996, 7,768 in 2003, 4,968 in 2009, and 4,373 in 2013. Fatalities between 24 h and 30 days following a traffic accident were 1,176 in 2003, 863 in 2009, and 779 in 2013, this being a similar reduction to the 24-h traffic fatalities, being equal to 10–20% the number of fatalities within 24 h of accidents for that same year (Fig. 1). The number of traffic accident-related injuries also fell over 9 consecutive years to

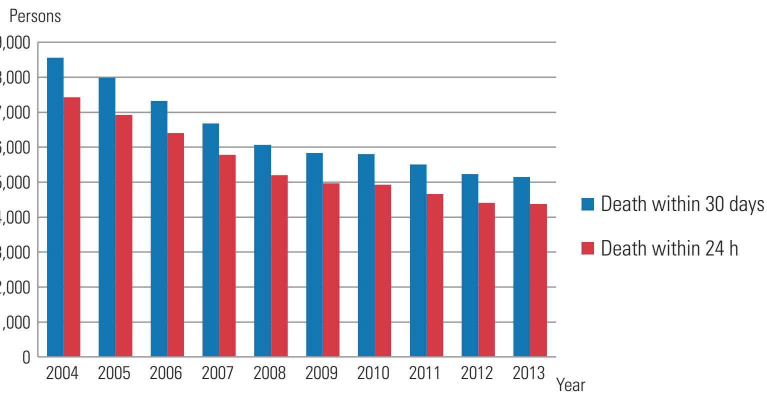


Figure 1. Traffic fatalities

781,494 in 2013, with approximately 6% of injuries being serious injuries and requiring over 30 days of treatment (Fig. 2).

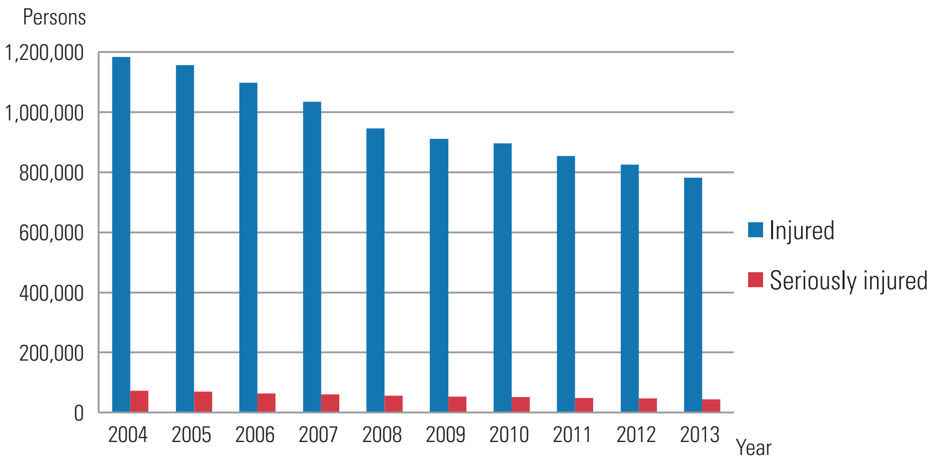


Figure 2. Injuries due to traffic accidents

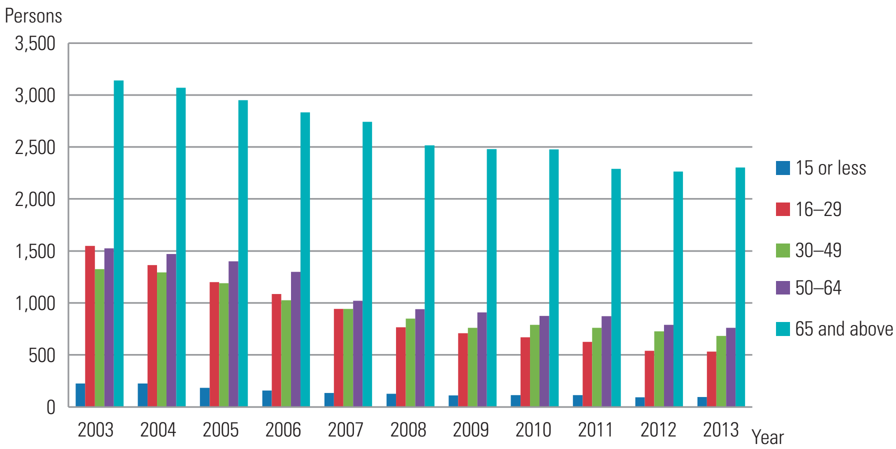


Figure 3. Traffic fatalities by age (death within 24 h)

This reduction in casualties is the result of several efforts, including legal efforts such as strengthening laws against drunk driving and making seatbelt usage mandatory, the development of accident-resistant road environments, automobile structural developments, improvements in public transportation facilities and medical rescue systems, and comprehensive accident prevention measures such as traffic safety education. Viewing casualty statistics by age, the ratio of fatalities and injuries among the elderly is relatively high, and the amount of reduction experienced among all age groups was smallest among the elderly; the rate of elderly fatalities is approximately 6.6 times that of other age groups, and the rate of serious injury is approximately 3 times as high (Fig. 3).[1)]

While the number of traffic accident-related fatalities has reduced for all age groups, the ratio of elderly fatalities overall is increasing since the reduction rate for elderly fatalities is small. To address this issue, since June 2009 persons aged 75 years or older wishing to renew their driver's license must undergo a cognitive function test, and must furthermore undergo a driving course designed for the elderly. Other traffic accident-prevention measures targeting elderly pedestrians will likely be particularly needed.[2)]

9.2 Damage due to traffic accidents

Table 1. Traffic accident damage by riding position in terms of mechanism of injury

1. Pedestrians
   - Injury due to bumper, hood, windshield
   - Injury due to being run over (tire marks, abrasion) or dragged
   - Primary injuries: Injury due to initial impact
   - Secondary injuries: Injury due to being flung up and colliding with the vehicle
   - Tertiary injuries: Injury due to impact with the ground
2. Drivers
   - Injury due to steering wheels, seatbelts, and air bags
   - Injury due to dashboards, windshields
   - Cervical spine injury (whiplash)
   - Lower extremity injury or pelvic fracture due to legs being extended to depress brake at impact
   - Injury due to being ejected from vehicle
3. Passengers
   - Injury due to steering wheels, seatbelts, and air bags
   - Injury due to dashboards, windshields
   - Cervical spine injury (whiplash)
   - Injury due to being ejected from vehicle

One feature of personal injury due to automobiles is that even when injury externally seems to be minor, internal damage can be quite severe. Automobile accident-related fatalities are categorized into deaths of pedestrians, drivers, and passengers, and other possible categorizations are for fatalities by motorcyclists and bicyclists. Each group has characteristic injuries (Table 1).

Injuries to pedestrians are categorized as those occurring due to the initial impact (primary injuries), those due to being flung up and subsequently colliding with the vehicle (secondary injuries), and those due to impact with the ground (tertiary injuries). Pedestrian injuries are highly dependent on the automobile's form and its speed at the time of impact. For standard passenger vehicles, pedestrian impact with the front bumper will result in lower extremity injuries at approximately bumper height, but in the case of hoodless cab-type vehicles, primary injuries will occur in the chest and lumbar regions. Such correspondence between primary injury locations and vehicle collision sites are vital to vehicle identification in hit-and-run accidents. In the case of low-speed (around 20 km/h) accidents, pedestrians are thrown in front of or to the side of vehicles. In the case of mid-speed (20–60 km/h) accidents, pedestrians tend to be flung up onto the hood or windshield. In high-speed (60–100 km/h) accidents, pedestrians are flung over the vehicle, and subsequently impact with the ground. In low-speed accidents where pedestrians are thrown in front of the vehicle, in some cases the pedestrian will be run over by the same vehicle, and when hit by cars at high speed, pedestrians will often sustain severe head injuries due to the subsequent impact with the ground.[3)] Brain damage is a very severe injury frequently seen in traffic accidents, and diagnosis and pathology of brain damage are important issues related to saving the lives of accident victims (Fig. 4).[4)]

Damage to drivers and passengers occurs when the vehicle collides with other vehicles or roadside structures, and resulting in contusions from being hit by objects from within the vehicle. The same can occur when vehicles roll over or when passengers are ejected from the vehicle. When the steering wheel impacts the driver's chest or abdomen, cardiac rupture and other serious injuries can occur. Seatbelts prevent the head and chest from impacting the windshield and steering wheel, and furthermore prevent ejection from the vehicle, which can result in serious injury. The usage or non-usage of seatbelts is an

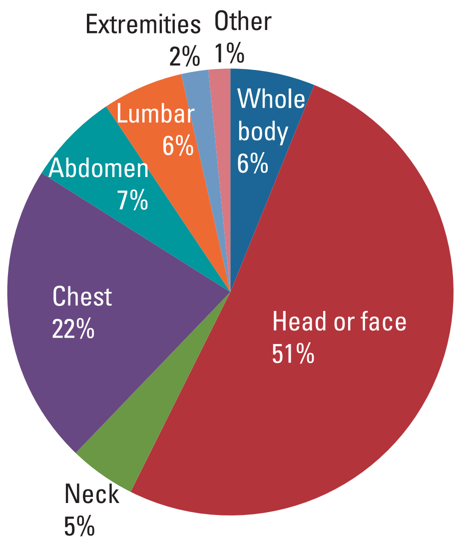


Figure 4. Fatalities by injury site

(2013; death within 30 days; 5,152 persons)

important predictor of injury severity. Seatbelt usage is required even when airbags are present; rapidly inflating airbags can cause serious contusions to the chest and abdomen if seatbelts are not worn.

Extent of damage is quantified to objectively study traffic accident damage. In 1971 the U.S. Association for the Advancement of Automotive Medicine created the Abbreviated Injury Scale (AIS) and performed research such as comparisons of treatment prognosis between multiple facilities, the relationship between collision speed and damage, and differences in damage when seatbelts were or were not worn. The AIS divides the body into seven areas (body surface, head, neck, chest, abdomen and pelvic organs, spine, and extremities), and assigns scores to each area based on damage according to 6 severity levels (1: minor; 2: moderate; 3: serious; 4: severe; 5: critical; 6: fatal). The largest score is also called maximum AIS. There is also the injury severity score (ISS), a severity evaluation method for multiple trauma that is calculated based on the AIS. In the ISS, the body is divided into six areas (head and neck, face, chest, abdomen, extremities and pelvic organs, and body surface), and assigns an AIS score of 1–5 to each injury. The ISS score is calculated by taking the maximal score from each area, and summing the squares of the top three AIS scores. Accordingly, the maximum value is 75. Alternatively, if any single location has an AIS score of 6, the ISS score is automatically calculated as 75. The ISS score represents severity well and is correlated with death rates, particularly in the case of multiple trauma patients. Analysis of mechanism of injury through analysis of three factors in traffic accidents—personal injury, accident vehicle, and scene of the accident—provides fundamental data for ensuring the safety of persons, vehicles, and road environments to prevent the occurrence of accidents (active safety) and reduces damage to passengers and pedestrians following accidents (passive safety).

9.3 Emergency medical care

9.3.1 Regional characteristics and the importance of immediacy in emergency medicine

Emergency medical care is the keystone of medicine, and is considered by all citizens to be the last bastion in the medicine for care of unexpected acute pathology.

Acute pathology is characterized by progress, regardless of differences in the degree of onset. A sudden headache may indicate subarachnoid hemorrhage. Chest pain may indicate acute myocardial infarction. A fall from a high location will likely lead to severe injuries caused by high-energy trauma. All of these cases require rapid transport to a hospital. Brain aneurysm rupture, which is known to be a cause of subarachnoid hemorrhage, has a high probability of fatality due to a second rupture on the same day of onset. Acute myocardial infarction can easily lead to a form of arrhythmia called ventricular fibrillation within 4 h of onset. High-energy trauma is highly likely to result in severe injury, and failure to determine a course of treatment by performing a diagnosis of the injury within 1 h of occurrence has a statistically significant increase in likelihood of death.[5)]

Maintaining an emergency care supply system that provides an "anytime, anywhere, anyone" level of care for such acute pathology is extremely important but at the same time very difficult. In Japan, differences in treatment outcomes for severe trauma have been reported by region and facility. To address this, Japan Trauma Care and Research developed a course called Japan Advanced Trauma Evaluation and Care (JATEC™) to demonstrate a protocol for trauma care, and is working toward its implementation through off-the-job participation throughout the country. The JATEC course was originally centered on doctors, but given the importance of team medical care, it was later extended to include nurses. Year after year, the course has been confirmed to contribute to substantial improvement of death rates due to trauma.[6)]

The status of emergency medical care takes on a different meaning between large and small cities. In many hospitals in large cities there are many specialists capable of providing leading-edge treatment, but for example in Tokyo, there have been unfortunate incidents of death believed to have been due to refusal of hospitals to admit patients or delays in transporting patients between hospitals. In contrast, hospitals in smaller cities often concentrate the role of emergency care for an entire region in one location, requiring them to admit patients with both minor and severe injuries, which presents the danger of losing the ability to function as a hospital. Setting aside the issue of which problem is easier to solve, given this situation it is necessary to consider the significance of the existence of emergency care within the framework of the community. Such problems must thus be solved through the combined efforts of the local hospitals, emergency services, fire brigades, police departments, and governments of each individual region.[7)]

9.3.2 Current status and problems related to time for emergency medical care

Time is of the essence for reducing death and sequela in emergency care, so it is necessary that ambulances reach emergency patients as quickly as possible, that hospital selection is rapidly performed, and that the time to arrival at the hospital is as short as possible. Nationwide data, however, indicates that the time to reach patients and the time required for hospital admittance continue to lengthen (Fig. 5). Multiple factors related to these increased delays have been identified at ambulance dispatch points, scenes of injury, and at hospitals, and measures have been taken to address each, but currently, effective solutions have not yet been found.

The Tokyo Fire Department has experienced an increase in the number of ambulance dispatch incidents, and so has increased its number of emergency crews to meet with increased regional populations and demands for appropriate emergency care (Fig. 6). Nonetheless, the number of dispatches per ambulance crew has not decreased; indeed, the number has increased from 1,488 in 1963 to 3,183 in 2013. There are a number of factors behind this increase, including increased reliance on ambulances for relatively minor situations, increased emergency service requests from the elderly, changes in disease trends, increased elderly population, and physiological characteristics of the elderly. These trends are similar across Japan, and due to the increased elderly population, about 40% of emergency patient transport is now for patients aged 70 years or older.

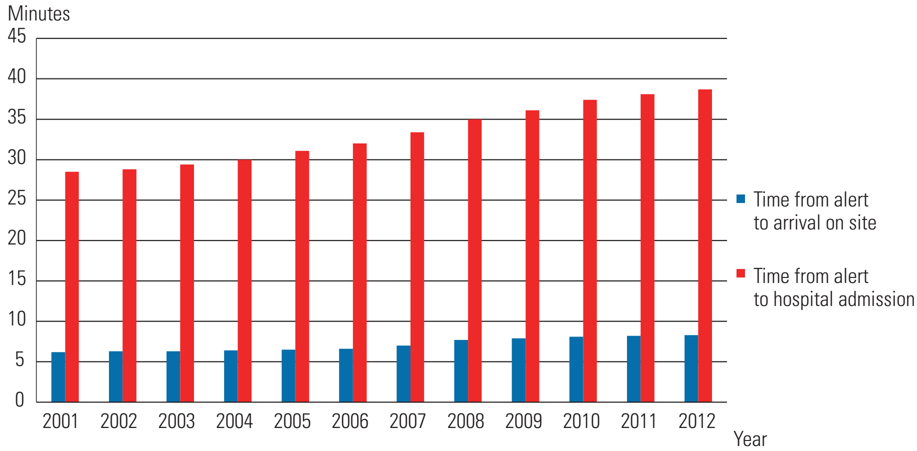


Figure 5. Trends in arrival time and time to hospital admission

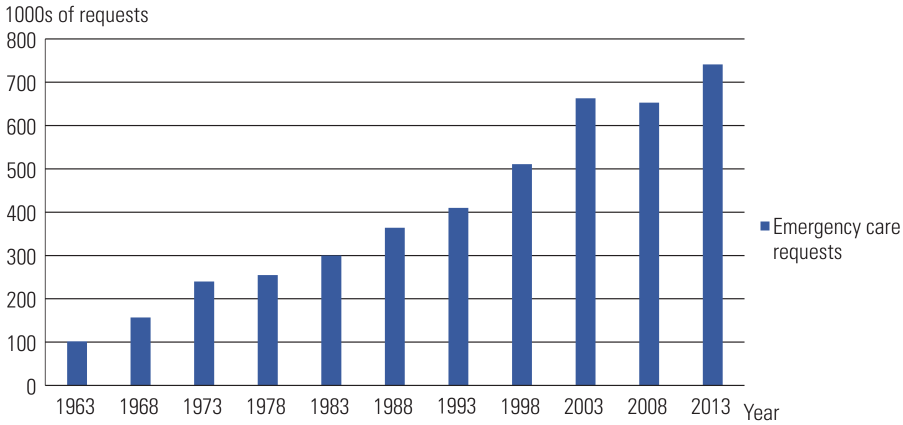


Figure 6. Trends in number of emergency care requests in Tokyo

Changes in blood pressure or state of consciousness in the elderly, which can rapidly worsen due to the effects of medication or difficulty in maintaining homeostasis, can in many cases be alleviated simply through body position adjustments or observation over time. In many cases, the situation improves during the wait for an ambulance to arrive, but the ambulance will often be used for transport to a hospital for examination, just in case. Unlike exogenous disease, inferring the prognostics of endogenous disease is considered difficult,[3)] and this difference is even more pronounced in the elderly. With the goal of better optimizing ambulance usage, in 2007 the Tokyo Fire Department became the first in Japan to offer a telephone-based triage service for the general public, aiding in the determination of whether pathologies are sufficiently acute to warrant requesting emergency services. This service, called "#7119,"[8)] helped to lower the number of emergency requests in 2008, but by 2013, numbers were again increasing. This illustrates the difficulty of restraining the number of incidents, given that emergency medical care is viewed as an administrative service.

9.4 Driving and health

Operating an automobile requires skillful judgment and operation on the part of drivers. It is thus inappropriate to drive while impaired due to the influence of fatigue, illness, alcohol, or drugs.

Illnesses that can affect automobile operation can be broadly classified into two types: chronic illness that is likely to hinder vehicle operation, and acute illness that can cause sudden death of the driver. The Japanese Road Traffic Act and other enforcement orders classify illnesses that can hinder vehicle operation as follows: 1) Schizophrenia with symptoms of hallucinations (excluding individuals that do not exhibit symptoms that prevent any one of the abilities required for safe vehicle operation, such as perception, prediction, decision-making, and operational control); 2) Epilepsy (excluding individuals in whom there is no risk of seizure recurrence, those in whom seizure recurrence does not result in movement disorders or impaired consciousness, and those in whom seizure recurrence occurs only during sleep); 3) Recurrent syncope (defined as disease that results in disturbance of consciousness due to transient ischemia of the whole brain, for which there is a possibility that episodes may recur); 4) Hypoglycemia unawareness (excluding individuals who are able to artificially modulate blood sugar); 5) Manic depression (including mania and depression, but excluding individuals that do not exhibit symptoms that prevent any one of the abilities required for safe vehicle operation, such as perception, prediction, decision-making, and operational control); 6) Sleep disorders with symptoms of severe drowsiness; 7) Other illnesses that involve symptoms that prevent any one of the abilities required for safe vehicle operation, such as perception, prediction, decision-making, and operational control; and 8) Dementia.

These illnesses can hinder vehicle operation present a risk of injury to others, and thus acquisition and renewal of driver's licenses is restricted for affected persons. Operation of automobiles by persons with chronic disease that causes episodes of impaired consciousness can result in the occurrence of serious accidents. Therefore, the Road Traffic Law establishes that 1) persons acquiring or renewing driver's licenses are required to respond to a questionnaire related to symptoms of certain diseases, 2) physicians who have diagnosed persons as having certain diseases that they feel may increase their chances of being involved in a serious accident may elect to submit forms stating such, and 3) persons suspected of having certain diseases can immediately have their driver's license provisionally revoked.[9)]

Sudden death is defined as the unexpected death of an otherwise healthy individual within 24 h of onset of an endogenous disease, and is most commonly due to cardiovascular disease such as myocardial infarction, cardiomyopathy, aortic aneurysm rupture, aortic dissection, cerebral aneurysm rupture, and hypertensive cerebral hemorrhage. Such disease can sometimes occur suddenly while driving, but while they can result in death of the driver, in most cases the driver is able to retain sufficient functioning to stop the car by the side of the road after onset, and thus they rarely result in the death of passengers or pedestrians. There are, however, cases in which sudden onset results in driver incapacitation, thus leading to a fatal traffic accident. Early diagnosis of underlying disease during standard health examinations and rapid treatment are therefore important for preventing sudden death while driving, which is classified as death by disease instead of by traffic accident. In cases where sudden death while driving is suspected, the cause of death is investigated, because distinguishing between such causes and lack of attention is important for elucidation of the cause of the accident and the dignity of the deceased.

Because alcohol impairs judgment and hinders vehicle operation, and can thus lead to traffic accidents, driving under the influence of alcohol is prohibited. In Japan, drunk driving is defined as operating an automobile with a blood alcohol concentration of 0.3 mg/mL or more, or with a breath alcohol

Table 2. Relation between blood/breath alcohol concentration and drunkenness

	Blood concentration (mg/mL)	Blood concentration (%)	Breath concentration (mg/L)	Drunkenness
Stage 0:	0.1–0.5	0.01–0.05	0.05–0.25	Euphoria: Feeling slightly intoxicated
Stage 1:	0.5–1.0	0.05–0.1	0.25–0.5	Mild drunkenness: Mild cognitive disturbance
Stage 2:	1.0–1.5	0.1–0.15	0.5–0.75	Light drunkenness: Cheerfulness, talkativeness, excitement
Stage 3:	1.5–2.5	0.15–0.25	0.75–1.25	Moderate drunkenness: Lowered decision-making, lowered ability to walk
Stage 4:	2.5–3.5	0.25–0.35	1.25–1.75	Strong drunkenness: Slurred speech, clouded consciousness
Stage 5:	3.5–4.5	0.35–0.45	1.75–2.25	Stupor: Loss of consciousness, hypothermia
Stage 6:	4.5–	0.45–	2.25–	Coma: Cardiac dysfunction, respiratory paralysis, death

concentration of 0.15 mg/L or more (breath alcohol concentration is taken as approximately 1/2000 that of blood alcohol concentration). In contrast, driving under the influence of alcohol is defined as driving in a situation where alcohol consumption may prevent normal automobile operation, regardless of blood or breath alcohol concentration. The relation between drunkenness and the degree of blood or breath alcohol concentration is important for determination of driving ability at the time of an accident (Table 2). Blood alcohol levels peak 1–2 h following consumption, then exhibit a gradual, linear decline as alcohol is metabolized. Maximum blood concentration increases with the amount of alcohol consumption, but the rate at which alcohol can be metabolized is fixed (a decrease of 0.16 mg/mL per hour), so large amounts of alcohol consumption will result in residual blood alcohol persisting over an extended time. It is therefore sometimes the case that one believes oneself sober the morning after heavy drinking, but in fact residual blood alcohol results in driving under the influence of alcohol. Note that in cases of hit-and-run accidents where alcohol concentrations could not be measured at the time of the accident, concentrations can be still estimated according to a mathematical equation, based on the amount of alcohol consumed or alcohol concentrations at a later time.[10)]

Other substances frequently abused in Japan, such as solvents, stimulants, and narcotics, can also act on the brain to lower decision-making abilities and prevent normal driving, and there have been accidents where solvents and stimulants have led to traffic accidents. There has been an increase in the abuse of dangerous drugs, and in the future it will likely be necessary to develop tests to screen for the use of illegal drugs, such as stimulants and dangerous drugs, by drivers involved in traffic accidents. Thorough implementation of such screenings would likely have a deterrent effect on driving while under the influence of illegal drugs, which can result in fatal traffic accidents.

9.5 Traffic safety and sleep

9.5.1 Two major factors pertaining to sleep and safe driving

Safe driving requires appropriate perception, decision-making, and control, three operational abilities that are disturbed by drowsiness. Good sleep is essential to preventing drowsiness.[11), 12), 13)]

A good understanding of accidents due to drowsiness calls for some fundamental background knowledge. Among other things, there are two major sleep-related factors that have an effect. One is the human body's circadian (internal) clock.[14)] The circadian clock functions to regulate daily rhythms through various bodily functions such as temperature and hormone control, and its effects on operational ability increase from morning until night. The effects then decrease to a minimum in the early morning, after which they begin to rise again (Fig. 7A).

The other factor is the duration of time spent awake.[15), 16)] Operational ability worsens as the time of continual wakefulness increases (Fig. 7B). Shortening the period of continual wakefulness by sleeping or napping can thus inhibit worsening of operational ability.

Interaction occurs between the effects of the circadian clock and time spent awake, which determines the actual level of operational ability. As an example, Fig. 7C shows the results of an experiment in which response time was measured after 36 h of being continually awake (participants were asked to press a button as quickly as possible after viewing a light, or other visual stimulation).[17)] Pressing a button in response to visual stimuli corresponds well to extremely fundamental driving skills, such as braking when seeing a red signal or using the steering wheel to avoid a stopped car. This data makes it easy to see that driving from late night to early morning or for long periods of time makes accidents more likely.

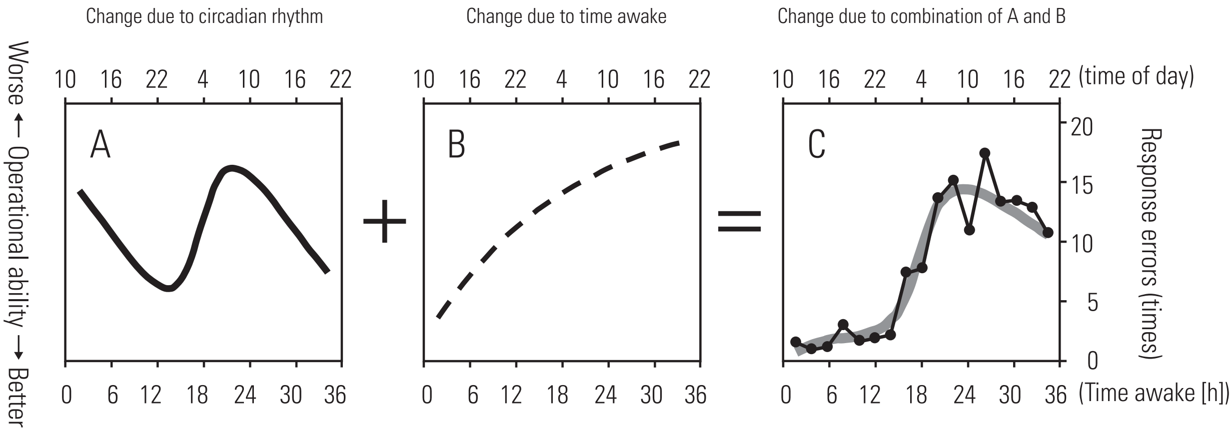


Figure 7. Effects of circadian rhythmicity and time awake on operational ability

The vertical axis represents the number of errors (lapses) in a reaction time test; C: Dots and black lines show measured values, gray lines are fitted according to A and B

In addition to the circadian clock and time spent awake, the amount and quality of sleep before driving are also closely related to safety. Not only sleep deprivation before automobile operation, but also chronically short sleep, increases the risk of traffic accidents.[18), 19)] Lowered quality of sleep often occurs due to environmental conditions such as noise or high temperature,[20)] work- or family-related stress,[21)] disorders such as insomnia or sleep-related breathing disorders,[22)] or other illnesses including depression or back pain.[23)] Such sleep quality-related problems increase the likelihood of traffic accidents.[24), 25)] Furthermore, the use of medications that can result in drowsiness should be avoided when driving.[26)]

Sleep-related problems may lead to traffic violations that can then cause motor vehicle crashes. Short sleep duration has been found to increase the frequency of driver inattention,[27)] and a group of sleep apnea patients was shown to commit more stopping violations than did a control group.[28)]

9.5.2 Significance of sleep in traffic safety measures

Traffic safety can be ensured using several approaches. As described above, sleep and sleep-related problems have a large effect on drivers, and thus there is a critical need for establishing effective measures to improve drivers' sleep by sharing knowledge regarding proper sleep among drivers and their families and employers, and also by developing workplace-based and other organizational programs for adequate sleep.[29)]

References

1) Traffic Bureau, National Police Agency. 2014. *Heisei 25 nen chu no kotsu jiko no hassei jokyo* [Traffic accident situation 2013]. (in Japanese)
2) Kibayashi, K., R. Shimada, and K. Nakao. 2013. "Temporal and Regional Variations in Accidental Deaths of Elderly People in Japan." *Medicine, Science and the Law* 53: 172–176.
3) Payne-James, J., R. Jones, S. B. Karch, and J. Manlove. 2011. *Simpson's Forensic Medicine*. 13th ed. Hodder Arnold.
4) Kibayashi, K., R. Shimada, K. Nakao, and A. Ro. 2012. "Analysis of pituitary lesions in fatal closed head injury." *American Journal of Forensic Medicine and Pathology* 33: 206–210.
5) Cowley, R. A., F. Hudson, E. Scanian, W. Gill, R. J. Lally, W. Long, and A.O. Kuhn. 1973. "An economical and proved helicopter program for transporting the emergency critically ill and injured patient in Maryland." *Journal of Trauma* 13, 12: 1029–1038.
6) Hondo, K., A. Shiraishi, S. Fujie, D. Saitoh, and Y. Otomo. "In-hospital trauma mortality has decreased in japan possibly due to trauma education." *Journal of the American College of Surgeons* 217, 5: 850–857.
7) Moriya, T., and K. Tanjoh. 2009. "Current status of emergency medical services and role of prehospital care." *IATSS Review* Vol. 34, No. 3: 260–269. (in Japanese)
8) Sakurai, A., N. Morimura, M. Takeda, K. Miura, N. Kiyotake, T. Shiahara, and T. Aruga. 2014. "A retrospective quality assessment of the 7119 call triage system in Tokyo: telephone triage for non-ambulance cases." *Journal of Telemedicine and Telecare*. http://doi.org/10.1177/1357633X14536347.
9) Kibayashi, K., and H. Shojo. 2002. "Incipient Alzheimer's disease as the underlying cause of a motor vehicle crash." *Medicine, Science and the Law* 42: 233–236.
10) Kibayashi, K, T. Sumida, H. Shojo, and M. Hanada. 2007. "Dementing diseases among elderly persons who suffered fatal accidents: a forensic autopsy study." *American Journal of Forensic Medicine and Pathology* 28: 73–79.
11) Mitler, M. M., M. A. Carskadon, C. A. Czeisler, W. C. Dement, D. F. Dinges, and R. C. Graeber. 1988. "Catastrophes, sleep, and public policy: consensus report." *Sleep* Vol. 11, No. 1: 100–109.
12) Åkerstedt, T. 2000. "Consensus statement: fatigue and accidents in transport operations." *Journal of Sleep Research* Vol. 9, No. 4: 395.
13) Folkard, S., D. A. Lombardi, and P. T. Tucker. 2005. "Shiftwork: safety, sleepiness and sleep." *Industrial Health* Vol. 43, No. 1: 20–23.
14) Golombek, D. A., and R. E. Rosenstein. 2010. "Physiology of circadian entrainment." *Physiological Reviews* Vol. 90, No. 3: 1063–1102.
15) Cajochen, C., S. B. Khalsa, J. K. Wyatt, C. A. Czeisler, and D. J. Dijk. 1999. "EEG and ocular correlates of circadian melatonin phase and human performance decrements during sleep loss." *American Journal of Physiology* Vol. 277, No. 3 Pt. 2: R640–649.
16) Dawson, D., and K. Reid. 1997. "Fatigue, alcohol and performance impairment." *Nature* Vol. 388, No. 6639: 235.
17) Van Dongen, H. P., A. M. Bender, and D. F. Dinges. 2012. "Systematic individual differences in sleep homeostatic and circadian rhythm contributions to neurobehavioral impairment during sleep deprivation." *Accident Analysis & Prevention* Vol. 45 Suppl.: 11–16.

18) Dawson, D., and K. McCulloch. 2005. "Managing fatigue: it's about sleep." *Sleep Medicine Reviews* Vol. 9, No. 5: 365–380.
19) Dorrian, J., M. Sweeney, and D. Dawson. 2011 "Modeling fatigue-related truck accidents: Prior sleep duration, recency and continuity." *Sleep and Biological Rhythms* Vol. 9, No. 1: 3–11.
20) Kayaba, M., T. Ihara, H. Kusaka, S. Iizuka, K. Miyamoto, and Y. Honda. 2014. "Association between sleep and residential environments in the summertime in Japan." *Sleep Medicine* Vol. 15, No. 5: 556–564.
21) Takahashi, M., K. Iwasaki, T. Sasaki, T. Kubo, I. Mori, and Y. Otsuka. 2012. "Sleep, fatigue, recovery, and depression after change in work time control: a one-year follow-up study." *Journal of Occupational and Environmental Medicine* Vol. 54, No. 9: 1078–1085.
22) Rosekind, M. R., and Gregory K. B. 2010. "Insomnia risks and costs: health, safety, and quality of life." *American Journal of Managed Care* Vol. 16, No. 8: 617–626.
23) Finan, P. H., and M. T. Smith. 2013. "The comorbidity of insomnia, chronic pain, and depression: Dopamine as a putative mechanism." *Sleep Medicine Reviews* Vol. 17, No. 3: 173–183.
24) Léger, D., V. Bayon, M. M. Ohayon, P. Philip, P. Ement, A. Metlaine, M. Chennaoui, and B. Faraut. 2014. "Insomnia and accidents: cross-sectional study (EQUINOX) on sleep-related home, work and car accidents in 5293 subjects with insomnia from 10 countries." *Journal of Sleep Research* Vol. 23, No. 2: 143–152.
25) Tregear, S., J. Reston, K. Schoelles, and B. Phillips. 2009. "Obstructive sleep apnea and risk of motor vehicle crash: systematic review and meta-analysis." *Journal of Clinical Sleep Medicine* Vol. 5, No. 6: 573–581.
26) Hetland, A., and D. B. Carr. 2014. "Medications and impaired driving." *Annals of Pharmacotherapy* Vol. 48, No. 4: 494–506.
27) Anderson, C., and J. A. Horne. 2013. "Driving drowsy also worsens driver distraction." *Sleep Medicine* Vol. 14, No. 5: 466–468.
28) Vakulin, A., P. G. Catcheside, C. J. Van Den Heuvel, N. A. Antic, R. D. McEvoy, and S. D. Baulk. 2011. "Increased rate of traffic law infringements during on-road metropolitan driving in obstructive sleep apnea patients." *Sleep and Biological Rhythms* Vol. 9, No. 3: 144–149.
29) Takahashi, M. 2012. "Prioritizing sleep for healthy work schedules." *Journal of Physiological Anthropology* Vol. 31, No. 1: 1–8.

Recommended Reading

1) Bloomberg, H., B. Svennblad, K. Michaelsson, L. Byberg, J. Johansson, and R. Gedeborg. "Prehospital trauma life support training of ambulance caregives and the outcomes of traffic-injury victims in Sweden." *Journal of the American College of Surgeons* 217, 6: 1010–1019.e2.
2) Czeisler, C. A. 2013. "Perspective: casting light on sleep deficiency." *Nature* Vol. 497, No. 7450: 13.
3) Takahashi, M. 2014. "Assisting shift workers through sleep and circadian research." *Sleep and Biological Rhythms* Vol. 12 (2): 85–95. http://doi.org/10.1111/sbr.12065.
4) Williamson, A., R. Friswell, J. Olivier, and R. Grzebieta. 2014. "Are drivers aware of sleepiness and increasing crash risk while driving?" *Accident Analysis & Prevention* 70: 225–234. http://doi.org/10.1016/j.aap.2014.04.007.
5) Ayas, N., R. Skomro, A. Blackman, K. Curren, M. Fitzpatrick, J. Fleetham, C. George, T. Hakemi, P. Hanly, C. Li, et al. 2014. "Obstructive sleep apnea and driving: A Canadian Thoracic Society and Canadian Sleep Society position paper." *Canadian Respiratory Journal* Vol. 21, No. 2: 114–123.
6) Strohl, K. P., D. B. Brown, N. Collop, C. George, R. Grunstein, F. Han, L. Kline, A. Malhotra, A. Pack, B. Phillips, et al. 2013. "An official American Thoracic Society Clinical Practice Guideline: sleep apnea, sleepiness, and driving risk in noncommercial drivers. An update of a 1994 Statement." *American Journal of Respiratory and Critical Care Medicine* Vol. 187, No. 11: 1259–1266.

Practical application projects for reference

Addressing issues associated with prehospital emergency transportation: 176–179
Dissemination and promotion of screening for sleep disorders: 180–183

Chapter 10

Laws and policies pertaining to traffic safety

This chapter focuses on laws and policies pertaining to traffic safety, provides basic information, and discusses issues to overcome for better future institutional design and implementation. More specifically, Section 10.1 provides an overview of the roles of laws and the legal framework for traffic safety, followed by discussions on developments in policies concerning traffic safety (Section 10.2), traffic safety regulation from the perspective of criminal law (Section 10.3), and the relationship between new traffic safety technologies and legal policy (Section 10.4). Section 10.5 provides a summary of this chapter, reviewing legal policies on traffic safety in light of recent active legal discussions on risk management.

10.1 The roles of laws and legal framework for traffic safety

10.1.1 Laws and securing transportation and safety: An overview of the relevant laws and legal framework

Securing safe transportation for the public has been a major responsibility of any country throughout history. Herbert Krüger (1905–89), a German scholar of public law, considered roads as an essential factor in a country's existence.[1] Today, the importance of international transportation has been rapidly increasing, and countries have taken various measures to secure safety in international transportation, signing treaties such as the International Convention for the Safety of Life at Sea (the SOLAS Convention) and the Convention on International Civil Aviation (the Chicago Convention).

In Japan, too, securing means of transportation and its safety is now a national issue as seen in efforts to secure mobility for the transportation-disadvantaged, such as senior citizens, and in countermeasures to dangerous bicycle riding. Since Japan is a nation of laws, its efforts to fulfill its duty in dealing with such issues must be rooted mainly in laws and regulations. In particular, when actions taken in this process restrict the rights and freedoms of citizens and impose obligations on them, these actions must be based on laws and regulations (*horitsu* and *jourei*).

Let us consider road traffic as an example. The Road Traffic Act (*doro kotsu ho*) enacted in 1960 is aimed at preventing dangers on the road, promoting the safety of other traffic and its smooth flow, and contributing to the prevention of obstacles due to road traffic (Article 1). The act contains provisions on the ways in which pedestrians and vehicles move, the driver's license system, and penalties and fines for violations. The Road Traffic Act is the most important law regarding road traffic rules, and based on this law, the National Public Safety Commission and the National Police Agency, as well as prefectural public safety commissions and police forces, conduct administrative activities related to road traffic safety.[2)] The law governing the construction and maintenance of road networks and the structure of roads is the Road Act (*doro ho*). The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has jurisdiction concerning this law, and the national, prefectural, and municipal governments perform their respective responsibilities in securing the safety of roads as physical infrastructure. Therefore, if an accident occurs due to a falling object from an overpass or the roof of an aging tunnel, the relevant government implementing the law may be held responsible for failure in road management (in, for example, a compensation lawsuit against the national government). However, in cases of traffic accidents caused by improper installation of traffic lights or damage caused to a third party due to unnecessary or inappropriate pursuit of a violating vehicle by a police car, the relevant police agency may be held responsible with regard to its authority or its acts or omissions. The driver's license system governed by the Road Traffic Act specifies a general mechanism for checking the aptitude of those who intend to drive an automobile. As for the people and companies whose business involves driving vehicles such as buses and taxis, the Road Transportation Act (*doro unso ho*), as a law regulating business operations, provides the basis for a separate mechanism of safety regulation (operations in the trucking business are regulated by the Trucking Business Act [*kamotsu jidosha unso jigyo ho*]). The law requires these business operators, among other things, to set safety management rules and have operations managers. For example, in response to the serious accident involving an express tour bus caused by an overworked driver on April 29, 2012, the MLIT revised the interpretation and implementation standards for the Ordinance for Enforcement of the Road Transportation Act, which led to strengthened regulations including restricted travel distances and the presence of a second driver.[3)]

10.1.2 Problems requiring multifaceted solutions and the division and comprehensiveness of administrative authority

As the overview presented above suggests, the laws governing transportation and its safety have the following characteristic: matters subject to relevant rules are divided according to the jurisdiction of different agencies (and their departments). In a sense, this division is needed by the administrative agencies and their activities because agencies have pursued specialization in order to respond to various administrative issues and their increasing difficulty. In addition, issues involving traffic safety do not arise conveniently according to the configuration of government agencies and thus often require cross-agency measures. For example, responses to the negative health effects of road-related pollution include not only creation of planting strips and installation of sound barriers by organizations responsible for constructing and managing roads, as well as the construction of underground roads, but also measures that treat automobile transportation as a source of pollution, such as exhaust gas regulations, road pricing, and road closure in cases of emergency. See, for example, the Supreme Court judgment for the Route 43 lawsuit (July 7, 1995; Supreme Court Reports [Civil Cases] (*Minshu*), vol. 49, no. 7, p. 1870), the Tokyo District Court judgment for the Tokyo air pollution lawsuit (October 29, 2002; Law Cases Reports (*Hanreijiho*), no. 1885, p. 23), and other judicial precedents regarding road-related pollution.[4)]

It is therefore important that comprehensive and consistent measures be formulated through talks among government agencies that have jurisdiction over different laws and through arrangements made by coordination bodies such as the Cabinet Secretariat and the Cabinet Office. Also, municipal governments, which are closest to the sources of problems and have comprehensive authority over local administrative issues including community development, are crucial actors in regard to legal policy for traffic safety. To implement measures incorporating the ideas devised by municipal and prefectural governments that have firsthand experiences of problems, in the second phase of Japan's decentralization reform, the laws and legal framework concerning roads and traffic safety were reexamined to a certain extent with respect to the requirements and limitations imposed by the national government, as seen in the permission of the use of own technical standards by municipal and prefectural governments with regard to the structure of roads, the abolishment of mandatory traffic safety planning by municipal governments, and the requiring of efforts for such planning.[5)]

With respect to the issue of traffic safety, the role of regulations set by regional and local governments is larger than it was in the past. Although various stakeholders have become involved, it is desirable that local residents increase their participation in the planning of traffic safety measures related to community development.

10.2 Implementation of traffic safety policies

This section discusses information dissemination, quality assurance, and utilization of non-life insurance which, like legal restrictions, play important roles as policy instruments for securing traffic safety. This section also considers international harmonization of automobile safety standards to show the growing importance of having an international perspective in traffic safety issues.

10.2.1 Information dissemination: The Japan New Car Assessment Program

Providing information is becoming an important policy instrument in various fields. A new car assessment program is a policy instrument in which information on the performance of automobile technologies is made public in order to promote development of automobile technologies by automobile manufacturers and proper selection of technologies by automobile users. New car assessment can be considered as a type of technological assessment. As a policy instrument, technological assessment supports decision-making through dissemination of information regarding various impacts of technologies.[6)] These impacts include not only safety risks and economic costs, but also social and cultural impacts. In this broader context, new car assessment is conducted with a focus on the safety performance of automobile technologies. The Japan New Car Assessment Program started in 1995, and initially emphasis was put on providing information about crash safety performance. Subsequently, information on the performance of pedestrian protection functions and child safety seats began to be provided. Today's new car assessment also covers preventive safety technologies.

10.2.2 Quality assurance: Assessment of transportation safety management

As technologies are rapidly advancing and being utilized in organizations, it is often difficult to ensure safety solely based on regulations that are distinct from each other. In such situations, there are ways to give rise to quality assurance that is achieved through business operators' voluntary efforts for improvement. Quality assurance by an organization refers to guaranteeing product quality to its customers by maintaining in-house communications intended for product quality improvement. For this purpose, organizations are expected to act proactively and autonomously and in a well-organized manner. This approach to quality assurance has been widely used in various fields including nuclear safety, medical safety, and food safety.

In the transportation sector, with consideration given to accidents such as the JR West Fukuchiyama Line accident of April 2005, the Japanese government began its efforts to introduce a mechanism that would check the entire quality assurance system of all transportation business operators including railway operators.[7)] A committee for examining preventive measures against public transportation accidents attributed to human error was created in June 2005, and an interim report was published in August. The report pointed out that to create a climate or culture of safety, it would be important for a business operator to create its own safety management system and to make a continual commitment to safety. The Omnibus Transportation Safety Bill stipulated the creation of a safety management system by business operators and, on the government side, the establishment of a safety monitoring body responsible for different modes of transportation and the creation of a transportation safety management system that would perform, among other things, safety management assessment. The bill also required business operators to prepare and submit their safety management rules and to appoint a general manager on safety and report the appointment. The safety monitoring body was mandated to assess business operators' transportation safety management systems. The results of such assessment are summarized for different modes of transportation (e.g., railway, automobile, sea transportation, and aviation) and are used as feedback for actual business operations.

10.2.3 Non-life insurance: Compulsory insurance and voluntary insurance

Non-life insurance not only secures compensation to victims of accidents and reduces feelings of insecurity at the societal level, but also has a preventive function in which accidents and damage are curbed because of insurance premium discounts/surcharges and other measures that adjust to hazards associated with the insured parties or properties.[8)]

For automobile accidents, the need for comprehensive compensation coverage is high because many people are potential victims of accidents. Without such coverage, it would have been difficult to introduce into society the technology called the automobile, which inevitably would produce a certain number of victims.

In Japan, there are two kinds of automobile insurance: compulsory insurance (automobile liability insurance/mutual aid) based on the Automobile Liability Security Act and voluntary insurance (automobile insurance/mutual aid). On the basis of automobile liability insurance and mutual aid, voluntary private insurance provides extra coverage. There is also the Automobile Liability Security Program in which the government provides compensation to victims of accidents caused by uninsured vehicles. The government initially provided reinsurance for 60% of automobile liability insurance in order to ensure compensation, but the government reinsurance program was abolished in 2002 due to the improved business foundation of insurance companies. The deregulation of the insurance industry that began in 1998 enabled companies to set their premiums independently, and they started to sell products that offer premium discounts for cars with high safety performance. As for voluntary insurance, incentive systems are implemented in which premiums change according to past driving history, and the resulting differences in premiums are expected to curb the number of accidents.

10.2.4 International harmonization of standards: The World Forum for Harmonization of Vehicle Regulations

Since automobiles are important in trade and direct investment, countries had incentives to internationally harmonize technical standards associated with safety and other factors.[9] The United States and the European Union created the Trans-Atlantic Business Dialogue in 1995 in a move toward mutual recognition of standards, and its main theme was harmonizing recognition of automobile-related standards. Subsequently, discussions were held in a trilateral group that included Japan, and progress was made in industry-led harmonization.

Against the background of this trend toward harmonization of standards, Working Party 29 of the United Nations Economic Commission for Europe, which was a Eurocentric intergovernmental commission, was rediscovered and started to play an important role in internationally harmonizing standards for automobile technologies. In 1999, Working Party 29 began to be called the World Forum for Harmonization of Vehicle Regulations. While this was happening, progress was made in international harmonization of individual items: the 1958 Agreement concerning mutual recognition of automobile technology standard certifications was revised in 1995, and a global agreement was adopted in 1998 among countries including Japan, the United States, and the European Union. For Japan, such international harmonization constituted one aspect of its international industrial policy.

10.3 Criminal regulations regarding traffic safety[10)–14)]

10.3.1 Characteristics of criminal regulations: comparison of criminal penalties and public-order penalties

To secure traffic safety, violators of transportation-related laws and regulations may receive criminal penalties. In other words, violations of such laws and regulations are not only subject to public-order penalties (fines), but also considered to constitute a crime. Therefore, there is a system in which such violations are legally condemned by imposing criminal penalties on the violators (criminals) with the aim that the same violations are prevented from recurring.

Similar to criminal penalties, public-order penalties (for disturbing order in the functioning of government administration) are legal sanctions against failure to comply with certain requirements (i.e., requirements regarding certain acts and omissions that contribute to achievement of traffic safety), but there are qualitative differences in the extent of sanctions between these two types of penalties. Both of them render adverse dispositions to violators, but criminal penalties provide the opportunity for strong legal condemnation of violators' actions. Accordingly, violators who receive a criminal penalty will have a criminal record and must accept various disadvantages, such as certain license restrictions, according to the severity of the criminal offence. For example, people driving an automobile over the speed limit would just pay a fine if the seriousness of the violation is within a certain range (e.g., a speed less than 30 km/h above the legal speed limit); however, if the violation is more serious (e.g., a speed equal to or greater than the abovementioned threshold), it would result in a fine as a criminal penalty and in a criminal record (entry in the offender list).

10.3.2 Criminal regulations pertaining to traffic safety

(1) Relevant laws and regulations

The criminal regulations pertaining to traffic safety are mainly based on the Road Traffic Act and the Act Concerning Punishment of Automobile Driving Resulting in Death or Injury (*jidosha unten shisho koi shobatsu ho*). The latter is an independent law that was created to define the crime of dangerous driving resulting in death or injury (*kiken unten chishisho zai*) and the crime of negligence in automobile driving resulting in death or injury (*jidosha unten kashitsu chishisho zai*), which had been defined in the penal code.(1)

(2) The Road Traffic Act

Main violations under this law, for which criminal penalties would be imposed, are listed in Table 1.

(3) The Act Concerning Punishment of Automobile Driving Resulting in Death or Injury

Main violations under this law, for which criminal penalties would be imposed, are listed in Table 2.

10.3.3 An example of applying the law

The following is an example of how the various penalties mentioned in Section 10.3.2 are applied.

Suppose Person A drove a car to a bar, and after drinking he tried to drive the same car home. When he got in the car, he was slightly drunk but remembered that he was sitting in the driver's seat and started the car (that is, normal operation of the vehicle would have potentially been impaired, but was not difficult). After that, while driving he lost consciousness due to intoxication (that is, normal operation of the vehicle became impossible). He therefore became unable to properly drive the car, and the car hit and killed a pedestrian. When this occurred, Person A regained consciousness but did not call

(1) The law was enacted in November 2012 and was implemented on May 20, 2013.

Table 1. Main violations for which criminal penalties would be imposed under the Road Traffic Act

Crime	Typical case	Statutory penalty	Legal basis[(2)]
Failure to drive safely	Inattentive driving, etc.	Imprisonment for up to 3 months, or a fine of up to 50,000 yen	Article 70; Article 119, No. 9
Fatigued driving	Drowsy driving, etc.	Imprisonment for up to 3 years, or a fine of up to 500,000 yen	Article 66; Article 117, Section 2-2, No. 7
Speeding	Violation of the speed limit	Imprisonment for up to 6 months, or a fine of up to 100,000 yen	Article 22; Article 118, No. 1
Driving under the influence of alcohol	Slightly drunk	Imprisonment for up to 3 years, or a fine of up to 500,000 yen	Article 65, Paragraph 1; Article 117, Section 2-2, No. 3
Providing alcohol	Providing alcoholic beverages to those who may drive under the influence of alcohol	Imprisonment for up to 2 years, or a fine of up to 300,000 yen	Article 65, Paragraph 3; Article 117, Section 3-2, No. 2
Drunk driving	Drunken staggering	Imprisonment for up to 5 years, or a fine of up to 1 million yen	Article 65, Paragraph 1; Article 117, Section 2, No. 1
Providing alcohol	Providing alcoholic beverages to those who may engage in drunk driving	Imprisonment for up to 3 years, or a fine of up to 500,000 yen	Article 65, Paragraph 3; Article 117, Section 202, No. 5
Failure to report an accident	Failure to report an accident to the police	Imprisonment for up to 3 months, or a fine of up to 50,000 yen	Article 72, Paragraph 1, 2nd part; Article 119, No. 10
Failure to provide aid	Failure to aid the injured	Imprisonment for up to 10 years, or a fine of up to 1 million yen	Article 72, Paragraph 1, 1st part; Article 117

Table 2. Main violations for which criminal penalties would be imposed under the Act Concerning Punishment of Automobile Driving Resulting in Death or Injury

Crime	Typical case	Statutory penalty	Penalty including that for unlicensed driving	Legal basis[(3)]
Dangerous driving resulting in injury	Impaired operation of the vehicle, resulting in injury	Imprisonment for up to 15 years	Imprisonment for 6 months to 20 years	Article 2
Dangerous driving resulting in death	Impaired operation of the vehicle, resulting in death	Imprisonment for 1 year to 20 years	Imprisonment for 1 year to 20 years (no additional penalty)	Article 2
Dangerous driving resulting in injury (less severe offense)	Potential impairment of normal operation, resulting in injury	Imprisonment for up to 12 years	Imprisonment for up to 15 years	Article 3
Dangerous driving resulting in death (less severe offense)	Potential impairment of normal operation, resulting in death	Imprisonment for up to 15 years	Imprisonment for 6 months to 20 years	Article 3
Avoiding detection of the influence of alcohol or other intoxicants in negligent driving resulting in death or injury	Negligent driving + death or injury + water intake, etc.	Imprisonment for up to 12 years	Imprisonment for up to 15 years	Article 4
Negligent driving resulting in death or injury	Negligent driving + death or injury	Imprisonment for up to 7 years, or a fine of up to 1 million yen	Imprisonment for up to 10 years	Article 5
Additional penalty due to unlicensed driving	Unlicensed driving	Penalty for unlicensed driving added to the statutory penalty listed above (see the column "Penalty including that for unlicensed driving")	The penalty for driving without a license varies by crime (as seen in the difference between the entries in this column and in the left column)	Article 6

(2) The relevant segments listed are those of the Road Traffic Act.

(3) The relevant segments listed are those of the Act Concerning Punishment of Automobile Driving Resulting in Death or Injury.

the police out of fear. He was drinking copious amounts of bottled water at the scene of the accident when he was arrested by dispatched police officers. After the arrest it became clear that his driver's license had already expired.

In this case, Person A is guilty of driving under the influence of alcohol, driving without a license, failure to report an accident, and failure to provide aid (all of which are crimes under the Road Traffic Act), as well as dangerous driving resulting in death or injury (or a less severe version of it; Article 3 of the Act Concerning Punishment of Automobile Driving Resulting in Death or Injury; the crime of driving without license under Article 6 of the Act also applies). With regard to the fact that his act of drinking water hindered accurate measurement of blood alcohol level, he is guilty of avoiding detection of the influence of alcohol or other intoxicants in negligent driving resulting in death or injury (Article 4 of the Act).

10.4 New traffic safety technologies and legal policy

This section examines judgments made from a legal policy standpoint with regard to how various new technologies that people adopt for increased convenience as participants in road traffic can be incorporated into the system of traffic safety rules. Let us look at a few examples. An example of a technology that provides assistive power to people who rely on human power to move from one place to another is the electric wheelchair, which enables those who cannot walk by themselves to move on streets as pedestrians. That is, they are separated from automobiles and share sidewalks with other pedestrians who are on foot. Since electric wheelchairs share space with people on foot, securing safety becomes an issue. The current system of rules deals with this issue by setting certain standards regarding the speed and shape of electric wheelchairs and permitting those that comply with the standards to share streets with pedestrians (see Supplemental Material 1 on the next page). Also, with regard to electric wheelchair users, as long as their wheelchairs satisfy these standards, they can operate their wheelchairs without being examined for their ability and aptitude to do so, unlike in the case of automobiles.[4]

These judgments in terms of legal policy are expressed in a provision of the current law stipulating that electric wheelchairs are treated as pedestrians for the purpose of applying the law.[5] Important components of the current system of traffic safety rules are a mechanism that distinguishes between the different ways in which roads are used, according to the types of participants in road traffic (e.g., pedestrians, bicycles, and automobiles) and a mechanism that examines the ability and aptitude of those who operate transportation machines such as automobiles. In both aspects, electric wheelchair users enjoy the same convenience provided by the law to the pedestrians. Electric-power-assisted bicycles also provide supplemental power to humans riding them, and those that satisfy certain standards are treated as

(4) According to the definition in the law, electric wheelchairs are not regarded as automobiles or motorized bicycles (Road Traffic Act, Article 2, Paragraph 1, Nos. 9 and 10).

(5) Road Traffic Act, Article 2, Paragraph 3.

Road Traffic Act, Article 2, Paragraph 1, No. 11-3 (definition of wheelchairs for the physically disabled)
It refers to a wheelchair that provides mobility to those with impaired walking due to a physical disability (motorized wheelchairs must satisfy the standards set forth in the relevant Cabinet Office Ordinance).

Ordinance for Enforcement of the Road Traffic Act, Article 1-4, Paragraph 1 (standards for motorized wheelchairs for the physically disabled)
With respect to Article 2, Paragraph 1, No. 11-3 of the law, the following standards are set by the relevant Cabinet Office Ordinance.

1. The size of the wheelchair must be within the following dimensional limits.
   a. Length: 120 cm
   b. Width: 70 cm
   c. Height: 109 cm
2. The structure of the wheelchair must satisfy the following conditions.
   a. The motor must be an electric motor.
   b. The speed of the wheelchair must not exceed 6 km/h.
   c. The wheelchair cannot have any sharp protrusion which can potentially harm pedestrians.
   d. The appearance of the wheelchair must be distinct from that of an automobile or motorized bicycle.

Supplemental Material 1. Definition of electric wheelchairs

bicycles along the same reasoning used in the case of electric wheelchairs (see Supplemental Material 2). In the future, the use of devices that enable assisted walking and utilize relevant robot technologies (i.e., personal mobility devices) will emerge as a concrete issue.

Let us now consider technologies that assist drivers of automobiles in perceiving their surroundings, processing information, making judgments, and operating devices, all of which are necessary skills in driving an automobile. These new technologies are very useful to drivers. The fact that they reduce the risk of accidents by overriding driver errors is also socially significant. Many of these technologies have already been commercialized as features available in automobiles. Also, assistive systems for safe driving are put to practical use as part of efforts to develop intelligent transportation systems. A question then arises how these new technologies should be introduced into the system of traffic safety rules.

It has long been the case in Japan that people can obtain a restricted driver's license that is only valid for automatic transmission vehicles. There is also a special driver's license that people who are unable to drive a regular automobile because of a disability of the arms or legs can obtain if they drive an automobile equipped with assistive devices enabling proper driving operations. In these cases, although the range of automobiles that can be legally driven is restricted, people using assistive technologies in performing necessary operations are not distinguished from regular drivers in terms of the freedom to drive an automobile on streets (e.g., where to drive and how to drive) or in terms of the responsibilities associated with participating in road traffic (e.g., the obligation to drive safely).

The current system of traffic safety rules requires drivers to assume many responsibilities, and drivers are subject to criminal or administrative penalties for their mistakes in driving. The driver's license

Road Traffic Act, Article 2, Paragraph 1, No. 11-2 (definition of bicycles)
A bicycle refers to a vehicle that is equipped with two or more wheels and is operated by human power with pedals or hand cranks (vehicles running on rails are excluded) but is not a wheelchair for the physically disabled, not a vehicle that assists walking, and not a vehicle for infants (bicycles with a motor for supplementing human power that satisfy the standards set by the relevant Cabinet Office Ordinance are included).

Ordinance for Enforcement of the Road Traffic Act, Article 1-3 (standards for bicycles with a motor for supplementing human power)
With respect to Article 2, Paragraph 1, No. 11-2 of the law, the following standards are set by the relevant Cabinet Office Ordinance.

1. The motor used for supplementing human power must satisfy all of the following conditions.
   a. It is an electric motor.
   b. When the bicycle is operated at less than 24 km/h, the ratio of human power to the power from the motor intended to supplement human power must be equal to or less than the value listed for each of the speed ranges shown in (1) and (2) below.
      (1) Less than 10 km/h: 2
      (2) 10 km/h or more but less than 24 km/h: 2 - [speed (in kilometers per hour) - 10] / 7.
   c. When the bicycle is operated at 24 km/h or more, the power from the motor intended to supplement human power must not be engaged.
   d. The structure of the motor satisfying conditions a to c is such that it is difficult to make modifications resulting in violation of any of conditions a to c.
2. The function of the motor intended to supplement human power must work smoothly, and the working of the function must not hinder safe operation of the bicycle.

Supplemental Material 2. Definition of electric-power-assisted bicycles

system provides a mechanism that excludes those who are not expected to fulfill such responsibilities. These facts are attributed not only to the way in which the automobiles currently driven are designed—they are designed to be operated by their drivers—but also to the freedom of movement in road transportation. People are free to choose when to move, where to move, and how to move, and the same applies to their automobile driving as a means of movement. At the same time, however, people enjoying such freedom are responsible for the adverse outcomes that can potentially result from driving. Also, in road transportation, drivers are numerous, are mutually unknown to each other, and are potentially dangerous to each other. Therefore, the fact that the drivers have uniform freedoms and uniform responsibilities makes situations in road transportation more predictable and increases people's trust in road transportation as a social function.

As long as drivers' freedom of movement is a given, the fact that new technologies reduce burden on drivers does not immediately mean that their responsibilities are reduced. With regard to automated driving systems, it makes sense, in terms of the legal framework, that relevant discussions are conducted along similar lines so long as drivers' freedom of movement is recognized. This framework is value-neutral, and we should put various values into practice in a harmonious manner based on it.

10.5 Legal policy concerning risk management

10.5.1 No one saw the danger

In order to secure traffic safety, various risk factors must be removed or controlled. In legal and policy studies, researchers are exploring ways in which modern risks, as opposed to dangers in the traditional sense which are qualitatively distinct, are handled, with consideration given to the trends in social system theory since the 1980s. Dangers in the traditional sense refer to those that can be expected based on empirical rules and can be predicted and handled based on trial and error in experiments and based on knowledge accumulated through experience. In contrast, risks in the modern context (those associated with genetic technology, nuclear technology, etc.) are characterized as follows: there has been little time to accumulate knowledge through experience; consequences are difficult to predict; and uncertainties are great. There are some problems in understanding the evolution from traditional dangers to modern risks in a simple linear manner, but an accident that occurred in 1921 provides an opportunity to consider the relationship between dangers and risks.

BASF, a German company, had a plant that produced ammonia, and since 1913 it had produced ammonia and nitrogenous fertilizer using a process called atmospheric nitrogen fixation (the Haber–Bosch process). The fertilizer was piled up out in the open, and parts of the pile that hardened because of absorbed moisture were broken up using dynamite before shipment. This way of handling the fertilizer led to a catastrophic explosion on September 21, 1921, leaving 509 people dead, 160 missing, and more than 1900 injured. The accident later became known as the Oppau explosion. Dynamite was used repeatedly, about 30,000 times, without problems. Also, no question was raised regarding the way the fertilizer was stored. Moreover, laboratory experiments using samples had shown that nitrogenous fertilizer does not typically explode in the manner it did in the accident. The company, its employees, neighborhood residents, and even experts did not expect such an accident.[15), 16)]

10.5.2 Government response to dangers and risks: The classic approach

To deal with dangers that are reasonably predictable, modern administrative laws have adopted certain approaches to regulations and relevant mechanisms as described below. The starting point is individual freedom. Individuals can act freely as long as they do not violate the rights and interests of others. The national government intervenes in order to prevent harm resulting from individuals' activities. The limits to such intervention are explicitly specified by laws. It is preferred that the government has less and less room for discretionary judgments.

Legislators use different legal mechanisms according to the need for regulation. For example, they adopt a reporting system if activities subject to regulation are not very dangerous and if it suffices to have information on these activities. In contrast, if the government needs to make specialized judgments regarding whether an activity can be permitted, it use a license (permit) system in which the government conducts reviews and issues licenses (permits) under relevant laws that set abstract licensing standards. In a license system, the national government and other entities monitor or supervise activities, issue recommendations or orders when dangers or harm arises, and, if no improvement is made, revoke the license.

The basic structure of such mechanisms and the ideas supporting it stem from an outdated notion that legislators and administrators can not only recognize, in a centralized manner, the dangers posed to the public by regulated enterprises, as well as the need for regulation, but also make specialized judgment. Here, difficulties in collecting information on regulated entities are not taken into account. Today's regulatory systems (e.g., the driver's license system based on the Road Traffic Act) still have such structures across different areas of government administration. The same applies to regulatory reform initiatives and deregulation initiatives, except for those related to outsourcing and extreme cases in which regulations are totally abolished.

10.5.3 Dealing with modern risks: The need for new organizations and approaches

The limitations of the traditional regulatory system become apparent when considering the risks associated with modern technologies including genetic engineering and nuclear power. It becomes important to consider not only the practical side including issues like the uneven distribution of information and limited government resources (human and physical) but also the legal side—how risk management systems can be designed and operated in the face of various uncertainties. The fact that proper risk management requires risk assessment conducted independently has been recognized in various areas (sometimes through painful experiences), and discussions have been held with regard to the ideal types of organizations for performing risk assessment and approaches to risk assessment.[17), 18)]

From the standpoint of organizations and approaches for risk assessment, the following considers the workings of the Japan Transport Safety Board (JTSB) in accident investigations and the issue involving the use of investigation information. In areas associated with traffic safety, some issues can be understood within the framework of traditional dangers, but there are new areas that require a new kind of risk assessment. Such new areas include automated driving systems and large-scale long-distance transportation systems utilizing linear-motor trains. Also, it must be considered whether traditional organizations and approaches can still deal with traditional dangers in transportation.

(1) JTSB: Investigation of causes and prevention of recurrence

In the case of transportation-related accidents, the law indirectly attempts to prevent their recurrence by imposing penalties on those who cause an accident (see Section 10.3 for discussions on criminal liability) and by recognizing the right of victims to claim damages (see Sections 10.1 and 10.2 for discussions on civil liability). At the same time, mechanisms to directly prevent recurrence of accidents are gradually becoming important. These mechanisms consist of various approaches and organizations that investigate the causes of accidents and propose measures to prevent their recurrence, independently from the issue of penalties and legal liability.

In Japan, the Aircraft Accident Investigation Committee was created in 1974 as a permanent affiliate body of the then Ministry of Transport to investigate the causes of aircraft accidents including the mid-air collision between an All Nippon Airways aircraft and a Japan Air Self-Defense Force fighter jet flying over Shizukuishi and the crash of a Toa Domestic Airlines aircraft in Hakodate, both of which occurred in 1971. In 2001, the committee was reorganized into the Aircraft and Railway Accident Investigation Committee, with its investigative responsibility expanded to include railway accidents. This reorganization was a response to the train accident that occurred in Shigaraki in 1991, the 2000 Hibiya Line accident, and requests from families of the victims in both accidents. In 2008, the JTSB, which is responsible for investigating causes of aircraft, railway, and maritime accidents, was created as there was a need to transfer authority over such investigation from the Marine Accident Inquiry Agency (the present-day Japan Marine Accident Tribunal). Put briefly, this need for transfer of authority arose because the International Maritime Organization decided to add to the SOLAS Convention a code stipulating that investigation of causes of maritime accidents be separated from disciplinary functions.

Whereas the traditional accident investigation committee was an affiliate body of the MLIT ("council (*shingi kai*)" in Article 8 of the National Government Organization Act), the JTSB is an external body (*gaikyoku*) of the MLIT (Article 3 of the Act) and thus has greater independence from the ministry.[19] The JTSB has newly granted authority to give recommendations directly to parties linked to causes of accidents (Articles 5 and 27 of the Act for Establishment of the Japan Transport Safety Board), to create its own rules (Article 16 of the Act), and to make decisions on personnel matters concerning secretariat staff (Article 55 of the National Public Service Act).[19]

(2) Accident investigation and criminal sanctions

The process of JTSB's activities aimed at preventing recurrence of accidents is mainly as follows: investigation of the accident site and physical evidence; interviews with parties linked to the cause of the accident; preparation of an accident investigation report; and recommendations and proposals. Relevant criminal proceedings by the police or prosecutor often take place simultaneously. It is therefore essential for them to properly perform their respective roles. For example, if materials collected by the JTSB in the course of its investigation are used in criminal proceedings, it could make parties linked to causes of the accident hesitate to provide necessary information.

Before the creation of the JTSB, this issue became apparent in a case of a defendant charged with professional negligence resulting in death or injury (Nagoya District Court judgment, July 30, 2004; *Hanrei Jiho*, no. 1897, p. 144). A summary of the case is as follows. In 1997, a Japan Airlines MD-11[(6)] preparing for landing over the Shima Peninsula exceeded its planned descent rate, which triggered the automatic control system. This became one of the reasons for the subsequent repeated vertical shaking of the aircraft's nose. Because of the shaking, one flight attendant died, and other flight attendants and passengers were seriously injured. The captain of the aircraft was later charged with professional

---

(6) According to the judgment, the aircraft's stability in vertical movements was low because the weight is shifted toward the back of the aircraft as the fuel tank was moved to the back to improve fuel economy and because the horizontal stabilizer was small by design. Due to this low stability, a computer-controlled pilot system was used.

negligence resulting in death or injury. In the first and second trials, the issue was whether the incident was caused by the automatic control system or by the captain's error in controlling the aircraft. The prosecutor used as evidence the accident investigation report prepared and published by the Aircraft Accident Investigation Committee, but the defense argued that the use of the report in the criminal suit violates the Chicago Convention and international standards specified in the Annex to the Convention.

Article 5.12 of Annex 13 of the Chicago Convention states that "[t]he State conducting the investigation of an accident or incident shall not make the following records available for purposes other than accident or incident investigation, unless the appropriate authority for the administration of justice in that State determines that their disclosure outweighs the adverse domestic and international impact such action may have on that or any future investigations" and lists as such records "all statements taken from persons by the investigation authorities in the course of their investigation."(7) Regarding this provision, the judgment provides the following explanation. The Annex is neither the Convention itself nor a convention that is adopted by consensus of the signatories or that is binding on the signatories. However, the Convention has adopted standards through the Annex in order to realize uniform procedures and, with the system of notification of differences, has required countries that adopt separate measures incompatible with standards specified in the Annex to notify their intention. Therefore, it is reasonable to think that countries not submitting a notification of differences are considered to be showing an intention to comply with the standards set in the Annex.(8) For this reason, in criminal proceedings the court needs to take into account restrictions in Article 5.12 of Annex 13 when it examines evidence.

The judgment interprets Article 5.12 as follows. The tenor of the Article shows that it is a provision restricting disclosure of records listed in it. Also, even though the purpose of accident investigations by the Aircraft Accident Investigation Committee is to prevent recurrence of similar accidents, the stipulation that in criminal proceedings for aircraft accidents, even the use of already widely available records must require consideration of its adverse domestic and international impact on current or future investigations puts an excessive restriction on criminal trials. Therefore, it is reasonable to interpret the Article as restriction on disclosure of records as seen in the tenor of the Article.

Based on these views, the court determined that since the accident investigation report had already been published, it was not subject to the restriction described in the Article and made a judgment based on the premise that the report could be used as evidence. More specifically, the court regarded the investigation report as an equivalent to a written expert opinion (*kanteisho*) specified in Article 321, Paragraph 4 of the Code of Criminal Procedure, accepted the report as evidence, and found the captain not guilty of negligence.(9)

---

(7) The note to Article 5.12 states the following: "Information contained in the records listed above, which includes information given voluntarily by persons interviewed during the investigation of an accident or incident, could be utilized inappropriately for subsequent disciplinary, civil, administrative and criminal proceedings. If such information is distributed, it may, in the future, no longer be openly disclosed to investigators. Lack of access to such information would impede the investigation process and seriously affect flight safety."

(8) At the time of the trial, Japan had not submitted a notification of differences with regard to Article 5.12.

(9) In passing, the issue of how Article 5.12 would be considered in a domestic criminal trial was not discussed in the second trial (Nagoya High Court, January 9, 2007; *Hanrei Taimuzu*, no. 1235, no. 136; not guilty verdict).

The above discussion shows that today's accident investigations must not only be separated from criminal sanctions, but also be consistent with international rules. The judgment implies that more critical situations can arise with regard to unpublished investigation reports.

10.5.4 Conclusion: Toward a Society where everyone has access to safe transportation

There are various dangers and risks associated with transportation. In addition to the problems of aging tunnels and commercial operators' prolonged driving resulting from deregulation which are discussed in this chapter, attention is currently being paid to reckless driving caused by dangerous (illegal) drugs. Efforts for securing safety are being made continuously. It is our hope that careful discussions on the theory of risk will continue between legal and policy scholars and researchers in other fields in order to enable design and implementation of a legal framework for realizing a society with safer transportation systems.

References

1) Krüger, Herbert. 1969. *Marktwirtschaftliche Ordnung und öffentliche Vorhaltung der Verkehrswege*. Darmstadt: Hestra Verlag.
2) Sekine, Kenichi, Shigeru Kitamura, Jun Kurata, Yoshiyuki Tsuji, Toru Ogino, Satoru Shimane, and Hayato Takagi, eds. "Doro kotsu no kanri" [Road traffic maintenance]. In *Koza keisatsu hou* Vol. 3: 148–525. 2014. Tachibana Shobo. (in Japanese)
3) "Special Supplement: Long Driving Hours and Fatigue." *IATSS Review* Vol. 38, No. 1, 2013. (in Japanese)
4) "Special Supplement: New Developments in the System of Road Laws–towards the Creation of Human-centered Roads." *IATSS Review* Vol. 35, No. 2, 2010. (in Japanese)
5) Saito, Makoto. 2011. "Chiho bunken kaikaku to doro kotsu gyosei" [Decentralization reform and administrative road traffic]. *IATSS Review* Vol. 35, No. 3: 233–238. (in Japanese)
6) Shiroyama, Hideaki. 2010. "Tekunoroji asesumento no tembo to kadai" [An overview of technological assessment and its issues]. *Jurist* No. 1409: 2–6. (in Japanese)
7) Oshima, Keitaro. 2006. "Unyu anzen ni kakaru aratana sukimu no jitsugen: unyu anzen manejimento hyoka no jisshi ni mukete" [Realization of a new scheme for transportation safety: assessment of transportation safety management]. *Transport Policy Studies' Review* Vol. 9, No. 2: 62–65. (in Japanese)
8) Misaki, Shigeki, Hideaki Shiroyama, and Hisakazu Hirose. 2003. "The preventative role of indemnity insurance in promoting public safety: The preliminary analysis of its function." *Sociotechnology research Network* Vol. 1: 198–207. (in Japanese)
9) Shiroyama, Hideaki. 2004. "Legal System for Safety: Sanctions and learning, role of third parties and international harmonization." *Shiso* Vol. 7, No. 963: 140–163. (in Japanese)
10) Imai, Takeyoshi. 2007. "Inshu unten taisaku rippo no igi to kadai" [Purpose and issues of legislating countermeasures against drunken driving]. *Jurist* Vol. 1342: 128–134. (in Japanese)
11) Imai, Takeyoshi. 2007. "Inshu unten taisaku toshite no bassoku no seibi" [Development of penalties for drunken driving as a countermeasure]. *Jurist* Vol. 1330: 24–31. (in Japanese)
12) Imai, Takeyoshi. 2005. "Kotsu jihan to sono keijihoteki kisei: kinji no jokyo o fumaete" [Traffic-related crimes and the regulation from the perspective of criminal law: based on the recent situations]. *IATSS Review* Vol. 30, No. 4: 465–469. (in Japanese)
13) Imai, Takeyoshi. 2014. "Kiken unten chishi shozai o meguru mondai jokyo" [Issues regarding the crime of dangerous driving resulting in death or injury]. In *Kotsu jiko to sekinin noryoku* [Traffic accidents and responsibility capacity], edited by Japan Association of Traffic Law, *Kotsuhokenkyu* Vol. 42: 129–175. (in Japanese)
14) Imai, Takeyoshi. 2008. "Kotsu jihan no houkisei o meguru gendaiteki kadai" [Today's issues regarding the regulation of traffic-related crimes]. *Crime and Delinquency* No. 157: 88–103. (in Japanese)
15) Yoshida, Tadao, ed. 1982. *Kagaku yakuhin no anzen* [Safety of chemical products]. Taisei-shuppan. 4–5. (in Japanese)
16) Yoshida, Tadao, ed. 1988. *Hannosei kagaku busshitsu to kakohin no anzen* [Safety of reactive chemical substances and explosive devices]. Taisei-shuppan. 31–32. (in Japanese)

17) Hasebe, Yasuo, ed. 2007. *Risuku gaku nyumon 3: horitsu kara mita risuku* [Introductory risk studies 3: risk from the perspective of law]. Iwanami Shoten. (in Japanese)
18) Shiroyama, Hideaki, and Yoichi Nishikawa, eds. 2007. *Hou no saikochiku III: kagakugijutsu no hatten to hou* [Reconstruction of law III: Development of science and technology, and law]. University of Tokyo Press. (in Japanese)
19) Uga, Katsuya. 2010. “Unyu anzen iinkai no genjo to kadai.” [Current condition of Transport Safety Board and its issues]. *Jurist* No. 1399: 10-20. (in Japanese)

Recommended Reading

1) Noguchi, Kikumi. 2009. “Norimono no anzen anshin” [Safety and security of vehicles]. In *Anzen, anshin no gyosei hougaku* [Safe and secure administrative jurisprudence], edited by Noguchi, Kikumi, and Masaharu Koda. Gyosei. (in Japanese)
2) Sekine, Kenichi, Shigeru Kitamura, Jun Kurata, Yoshiyuki Tsuji, Toru Ogino, Satoru Shimane, and Hayato Takagi, eds. 2014. “Doro kotsu no kanri” [Road traffic maintenance]. In *Koza keisatsu hou* Vol. 3: 148–525. Tachibana Shobo. (in Japanese)
3) Beck, Ulrich. 1986. *Risikogesellschaft*. Frankfurt am Main: Suhrkamp Verlag.
4) Calabresi, Guido. 1985. *Ideals, Beliefs, Attitudes, and the Law*. New York: Syracuse University Press.
5) Hasebe, Yasuo, ed. 2007. *Risuku gaku nyumon 3: horitsu kara mita risuku* [Introductory risk studies 3: risk from the perspective of law]. Iwanami Shoten. (in Japanese)
6) Shiroyama, Hideaki, and Yoichi Nishikawa, eds. 2007. *Hou no saikochiku III: kagakugijutsu no hatten to hou* [Reconstruction of law III: Development of science and technology, and law]. University of Tokyo Press. (in Japanese)

Practical application projects for reference

Creating installation guidelines for tactile ground surface indicators (braille blocks) for the visually impaired: 184–187
Ensuring urban public transportation mobility for people with intellectual disabilities: 188–191
A study on the level of service for local public transport to secure basic daily life: 192–195
Traffic safety and traffic enforcement: 196–199
Interdisciplinary research on the criminal charge of dangerous driving causing death or serious injury: 200–203
Smoothly promoting urban development for transportation through collaboration between government and local organizations: 204–207

Chapter 11
Sustainable growth—An economic perspective

11.1 Cost-benefit analysis

11.1.1 The purposes and theoretical foundation of cost-benefit analysis

Cost-benefit analysis (CBA) is applied to evaluate the economic effect of transportation facilities such as roads and railways and to support decisions regarding whether to take on projects.[1)] A federal waterway project by the Tennessee Valley Authority, which was begun during the 1930s as part of the New Deal in the United States, was the first systematic evaluation using CBA. The purpose is to determine whether a sufficient development effect would be realized when investing the large amounts of money required to construct dams and other massive projects.

CBA is applied not only to transportation facilities but to a wide range of evaluations for public investment. The basic idea is to calculate and compare in terms of monetary units the costs required for a project and the benefits derived from it. In the case of transportation facilities, monetary costs include those required for development (construction), ongoing maintenance, and other costs paid by public entities. There are also cases where negative effects to society resulting from the project, such as worsening of the environment, are included in the calculation as additional costs or negative benefits.

The main benefits from transportation facilities include benefits from timesaving, benefits from reduced movement costs (in the case of road development, fuel savings), benefits from improved safety, and benefits from improved comfort. Due to the nature of transportation facility development, benefits due to time savings account for a majority of the overall benefits. Several evaluation methods have been developed for costs and benefits such as time, safety (reduced accident risk), and comfort.

11.1.2 Evaluation criteria in CBA

Because of limitation of project budgets (financial resources), CBA is applied not to determine whether projects should be carried out, but rather to make a relative comparison for selecting between alternatives. There are three main criteria for project evaluation:

(1) Net present value method

Net present value is given by the following equation:

$$NPV = B - C - K = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+i)^t} - K$$

Here, *NPV* is the net present value, *B* is the present value of total benefits in base year 0, *C* is the present value of total maintenance costs in base year 0, *K* is the present value of construction costs in base year 0, *t* is the year, *T* is the evaluation term (durability in years), B_t is the benefits in year *t*, C_t is the maintenance costs in year *t*, and *i* is the social discount rate. In this evaluation method, the larger the NPV, the better the project.

(2) Benefit-cost ratio method

In this method, the larger the benefit-cost ratio, the better project. Benefit-cost ratio is defined as the ratio of the benefits of a project relative to its costs. In practice, two ratios can be used: $(B–C)/K$, which is the net benefits per unit of investment (construction costs); and $B/(C+K)$, which is the ratio of gross benefits to total costs. As both ratios represent cost-benefit ratios, it is necessary to choose in advance which ratio is used for the project appraisal.

(3) Internal rate of return method

Internal rate of return represents how much the rate of return from an investment increases, and the larger the internal rate of return, the better the project. The internal rate of return *r* is calculated by solving the following equation:

$$\sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = K$$

Internal rate of return is the criterion most consistent with economic theory. However, in cases where huge costs occur at the end of the evaluation period, such as when nuclear power plants are decommissioned, *r* can sometimes represent multiple possible solutions. Note that this rarely occurs in transportation improvement projects, so this method is recommended for the project evaluation.

11.1.3 Foreign exchange rate issues

In cases where funds are procured domestically, the evaluation methods described above can be applied regardless of whether funding will be through taxes or bonds. In cases where funding occurs through international investment, however, variation in future foreign exchange rates must be taken into account. In developing countries in particular, it is important that project evaluations consider the ability of the nation to repay foreign debt.[2), 3)]

11.2 Balanced and unbalanced growth

11.2.1 Theories of balanced and unbalanced growth

(1) Nurkse's balanced growth theory

The scale of a country's economy is determined by its trading conditions with other countries, in addition to other factors including the three major factors of production (land, private capital, and labor), as well as the country's saving rate, inflation rate, social overhead capital, and technology level. There is thus a wide variety of aspects for analysis in economic growth theory, one of which is research regarding economic growth paths.

Nurkse's balanced growth theory[4)] is one perspective regarding the path that a country takes during economic growth. Nurkse gave a lack of private investment as one cause related to the failure of developing countries to realize economic growth, and proposed balanced growth as a way of inducing private investment, on the assumption that balanced increases of production would expand markets. This theory is not well supported in recent years.

(2) Hirschman's unbalanced growth theory

Another approach is Hirschman's unbalanced growth theory.[5)] There are various difficult-to-solve problems that impede economic growth in developing countries, and such countries do not possess sufficient resources or capital to simultaneously solve them all. Accordingly, to pursue rapid economic development, the best strategy is to focus investment of resources and capital on strategic growth industries, and to maintain such a disequilibrium. Such strategic industrial growth would later have positive repercussions for other industries and contribute to nationwide economic growth.

11.2.2 Social overhead capital and private capital

Unbalanced growth theory can be applied to the balance between social overhead capital (public investment) and private capital (private investment). Figure 1 shows the path of each growth strategy, with A as a departure point and B as a destination. Three examples of growth paths between points A and B are shown. The horizontal axis indicates stock levels of social overhead capital, and the vertical axis indicates stock levels of private capital. In each case higher stock levels indicate

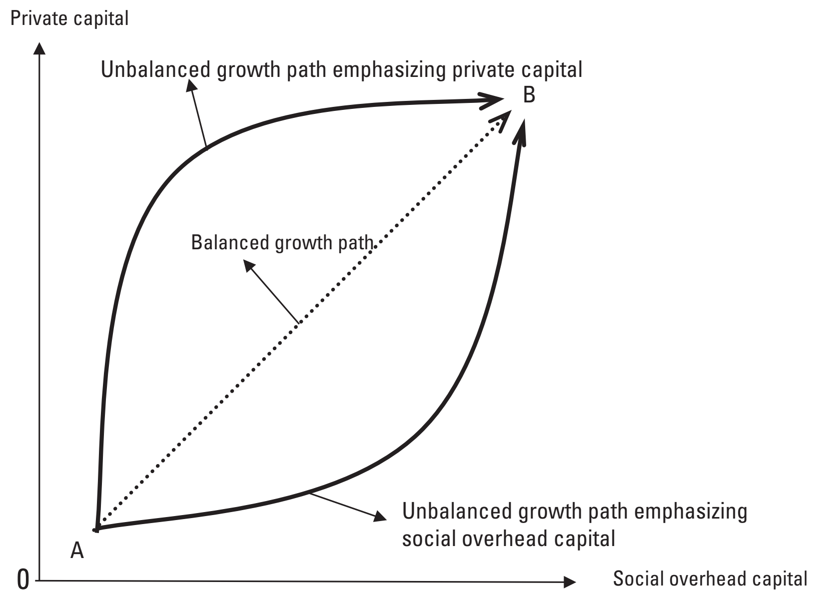


Figure 1. Balanced and unbalanced growth paths

higher potential productivity and thus higher potential economic growth.

In Fig. 1, the dotted line at a 45° angle is the path of balanced growth. In other words, investment occurs in a balanced manner such that marginal productivity is equalized between private and social overhead capital. In contrast, the curve at the top is a growth path in which private capital takes precedence over social overhead capital, and the curve at the bottom conversely prioritizes social overhead capital development. The issue at hand is the speed and cost required to move from A to B. Unbalanced growth theory states that an unbalanced growth path arrives at B more quickly and at a lower cost (specifically, a lower opportunity cost of capital) than the balanced path does.

Yet when considering whether to prioritize private or social overhead capital, it is insufficient to consider only the opportunity cost of capital. This is because while decision makers behind private-sector investment are private individuals, social overhead capital investment is exclusively a public entity. This is particularly true in the case of transportation facility development, where even within the same country the emphasis on private or social overhead capital will vary from region to region.

In cases where economic growth is so high that social overhead capital development cannot keep up, an unbalanced growth route that emphasizes private capital will be taken. From the viewpoint of transportation facility development, this is a case of transportation social overhead capital development aimed at keeping up with emerging demand. In other regions where private economic activities are stagnant, the government often may undertake transportation facility development for regional vitalization, which means that the government takes an unbalanced growth path that emphasizes social overhead capital. This is an example of transportation social overhead capital development that precedes economic development. In this case, failure to attain a sufficient regional development effect would result in failure to reach point B and the development of transportation facilities could be considered wasteful.

11.2.3 Forward and backward linkage effects

There are two types of economic effects resulting from public investment in transportation facilities: forward linkage effects and backward linkage effects.

Forward linkage effects are benefits (economic effects) from public services provided by the facilities developed through public investment. In other words, these are effects in which public investment results in increased social overhead capital stock, thus increasing potential productivity. The forward linkage effects of a project are recorded as benefits of the project in CBA.

Backward linkage effects are the economic effects of increased demand for a resource that is devoted to public investment, in particular economic effects in the regional economy. In other words, public investment activity results in increased demand for materials and labor, thus increasing income to material and labor suppliers. Backward linkage effects are often emphasized as being important economic effects of public investment programs for regional economies.

11.3 Economic policy against traffic congestion[6)]

11.3.1 What is congestion?

Congestion is the result of a concentration of relatively large demand in comparison to the capacity of facilities or equipment, and causes many monetary and nonmonetary costs that do not arise in cases of no congestion. In the transportation area, these include problems such as crowding on trains and congestion on road networks. In any case, it is assumed that supply levels cannot be changed in the short-term and that collective consumption is possible up to a certain level. Exceeding that level results in external diseconomies, indicating conditions that hinder the intended use. In this paper, we mainly deal with road congestion problems that many cities in the world suffer.

11.3.2 Economic understanding of congestion

Roads are a resource for which collective consumption is possible up to a certain level, allowing users to drive smoothly. However, when a road becomes congested, the driving speed on the road decreases, increasing costs such as time and fuel costs required to reach a destination.

Figure 2 shows such an example, with traffic flow on the horizontal axis and required costs on the vertical axis. Road capacity F_0 is the upper limit on possible equal consumption, and when automobiles in excess of this limit enter into the road, marginal costs begin to increase. In other words, the inflow of additional traffic results in decreased driving speed and increased time requirements for each driver, increasing marginal private costs. All drivers experience this increased cost resulting from the inflow of additional traffic in a similar way, so the marginal social cost curve diverges.

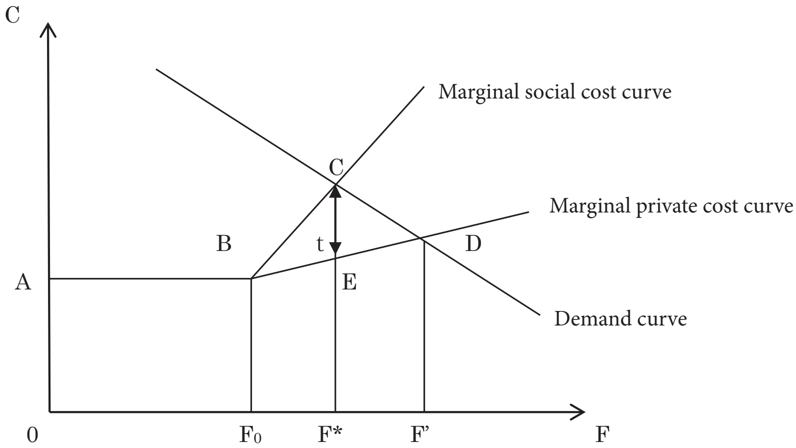


Figure 2. Occurrence of congestion

Following the concept of a Pigovian tax from microeconomics, this external diseconomy can be internalized by imposing a tax rate t, allowing attainment of an optimal congestion level F*.

11.3.3 Example of introduction of a congestion charge

Road congestion is a significant problem in many cities throughout the world. Although the aims are various, many cities such as Singapore, Oslo, and London have introduced congestion charging to downtown areas. London was the first city in an industrialized nation to attempt this, with a scheme designed to reduce inner-city traffic.

Beginning with the 1964 Smeed Report, there have been many studies and discussions on introducing a road congestion charge in London, but establishment of the Greater London Authority in 1997 and the 2000 election of a mayor who supported the idea laid the groundwork for actual implementation. In 2003, the London Congestion Charging Scheme was introduced for improving traffic flow. Under this scheme, automobiles entering areas designated by Transport for London between 7:00 and 18:00 on weekdays were subject to a charge of £5 per day. The charge was incrementally raised, and as July 2014 stands at £11.5 per day. Signs such as the one shown in Fig. 3 are posted at entrances to the congestion charge zone, and cameras record vehicle license plates to create records of who should be charged. All the money collected as a road congestion charge is designated for use toward developing and maintaining public transportation.[7]

Figure 3. Entrance sign in London indicating the congestion charge zone[(1)]

According to a published fact sheet, the congestion charging scheme has resulted in a 27% reduction in the number of vehicles in the congestion charge zone, as compared to 2002 figures before the introduction of the scheme. Bicycle usage has increased by 66%, indicating a shift away from the use of automobiles.

11.4 Economic policy and environmental problems[6]

11.4.1 Transportation and environmental problems facing modern society

There are many environmental problems caused by transportation, including air pollution, global warming, noise pollution, and vibration. In particular, many countries are working hard to develop measures for reducing atmospheric pollutants and greenhouse gas emissions. All modes of transportation increase environmental load to some extent, but on a per-emissions-unit basis automobiles are particularly problematic.

Atmospheric pollutants have a direct negative effect on human health, and materials such as nitric oxides, sulfur oxides, and particulate matter are generated in areas with many automobiles. Global warming is a result of the production of large quantities of greenhouse gases, with carbon dioxide considered to be a particularly large contributor. Carbon dioxide itself does not have a direct effect on human health, but it is believed that we are producing it in such large quantities that we are increasing the temperature of the Earth's surface, which in the future will lead to large effects such as rising sea levels and changes in vegetation.

11.4.2 Understanding environmental problems from an economic perspective

In economics, environmental problems are treated as the results of external diseconomies that lead to

(1) From the Transport for London website

overuse of a given service. Such overuse creates deadweight loss, so social surplus is not maximized.

As Fig. 4 shows, a Pigovian tax can internalize this external diseconomy by imposing a tax rate t that attains an optimal level F*.

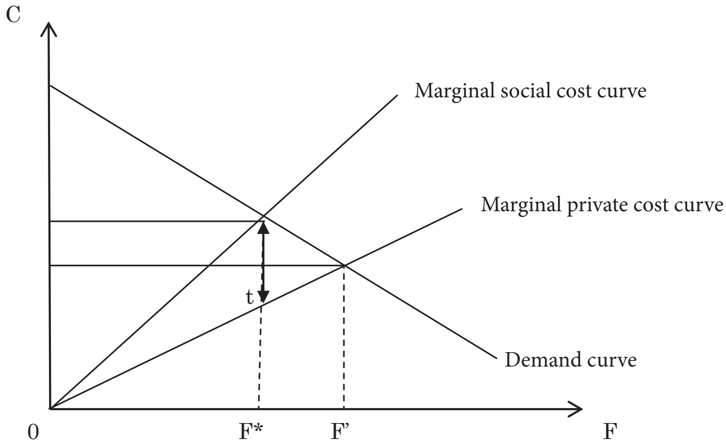


Figure 4. Environmental diseconomies and Pigovian taxation

11.4.3 Measures for addressing environmental problems

As discussed in the section above, environmental problems are caused by excess gaseous and particulate emissions. Measures that can be considered for reducing such emissions from automobiles can be categorized as those that (1) improve automobile performance, (2) suppress automobile usage, and (3) promote efficient automobile usage. Respective examples of such measures are (1) lowering the discharge rate of pollutants an automobile releases, (2) suppressing automobile usage through a switch to public transportation, and (3) reducing the number of vehicles used through more efficient utilization of automobile space.

A number of policy techniques can be applied to realizing such measures, but economic methods that utilize market mechanisms can allow for smoothly achieving these goals.

In the case of (1), reducing the acquisition and holding taxes associated with environmentally sound vehicles are effective; consumers would be more likely to select economically sound vehicles that carry a lower tax burden, thereby pushing automobile manufacturers to develop more of such vehicles and improving the average fuel consumption of new vehicles and improving the average performance of vehicles on the road. In the cases of (2) and (3), as described in Section 11.4.2, additionally imposing fuel taxes can promote higher efficiency at the usage level.

11.4.4 Economic instruments targeting the automobile environment in Japan

In Japan, a policy called the “greening of automobile-related taxes” has been implemented since 2001 with the goal of improving the environment through increased automotive performance. This policy lowers acquisition and holding taxes for

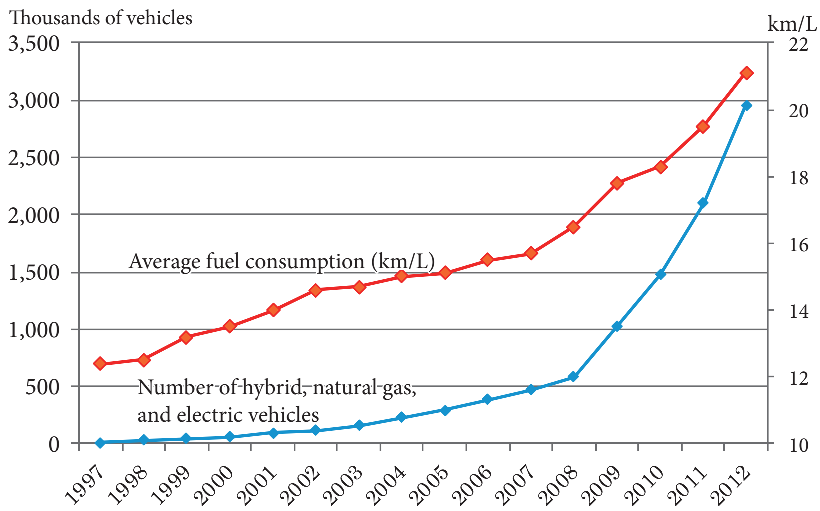


Figure 5. Performance improvement trends for automobiles in Japan

exceptionally environmentally friendly vehicles, while increasing taxes for vehicles with poor environmental performance.

This has resulted in consumers selecting more low-emission vehicles with lower taxes and in manufacturers making efforts to improve environmental performance of vehicles, thereby increasing ownership rates of hybrid, electric, and natural gas vehicles and improving overall per-liter fuel efficiency (Fig. 5). Such efforts have resulted in a trend of reduced carbon dioxide emissions from the transportation sector in Japan.

11.5 Economic regulations and deregulation

11.5.1 Regulations on transportation services

Transportation operations are generally considered susceptible to public intervention. Regulations can be roughly divided into "social regulations" and "economic regulations," with social regulations being qualitative regulations related to safety and the environment, and economic regulations being quantitative regulations related to effects on market supply and demand. Economic regulations are further categorized as price regulations and entry regulations. The supply and demand of transportation industries in particular have been adjusted, with public competition inhibited. In recent years, however, there has been a worldwide movement toward deregulation, with the goal of improved efficiency through competition in transportation markets.

11.5.2 Necessities and limits of regulation

One might ask why transportation markets in particular have long been subjected to economic regulation. One reason is that economies of scale in a given market are believed to lead to natural monopolies. Economies of scale often occur in industries with large fixed costs, and when companies freely compete, they bring down the prices, compete on service quality, and create "destructive competition." When competitors leave the marketplace and a natural monopoly has arisen, the victor is free to enjoy monopoly benefits and consumers will then be faced with monopoly prices. Furthermore the investments made by competitors that leave the market become "sunk costs" that cannot be recovered, representing a social loss.

Transportation markets have many of these features, and the high demand for transportation services would result in large effects, so long-lasting monopolies and oligopolies have been accepted in exchange for their being the subject of price regulations. Note that price regulations have been applied under the "full cost principle," which holds that necessary revenue equates to costs occurring under efficient management plus a fair profit.

However, the full cost principle does not provide operator incentives for cost reduction, and has led to inefficient management and further increased pricing. According to the theory of contestable markets presented by Baumol and others since the mid-1970s, this led to changes in public intervention in the transportation industry.[8)]

11.5.3 Contestable market theory

A contestable market is one with free entry and with no cost associated with leaving the market, allowing hit-and-run strategies. When a market is completely contestable, existing companies act efficiently, for reasons described below.

In the case where an existing company has a monopolistic or oligopolistic market and thus enjoys excessive profits, new companies can enter the market offering a lower price, thereby capturing all the customers and making a profit. In response to this, an existing company offer equivalent or lower prices, the new company will lose their profits, forcing them out of the market. By the same theory, even in the case where an existing company has a monopolistic market, one in which entry and exit by new companies does not entail sunk cost, the threat of new participation promotes the setting of efficient prices.

11.5.4 Expansion of deregulation

Taking contestable market theory as a theoretical background, in 1978 the United States deregulated domestic airline services, and after that, transportation segment deregulation spread around the world. Examples include bus and airline industries in the United Kingdom, as well as the airline, taxi, and trucking industries in Japan.

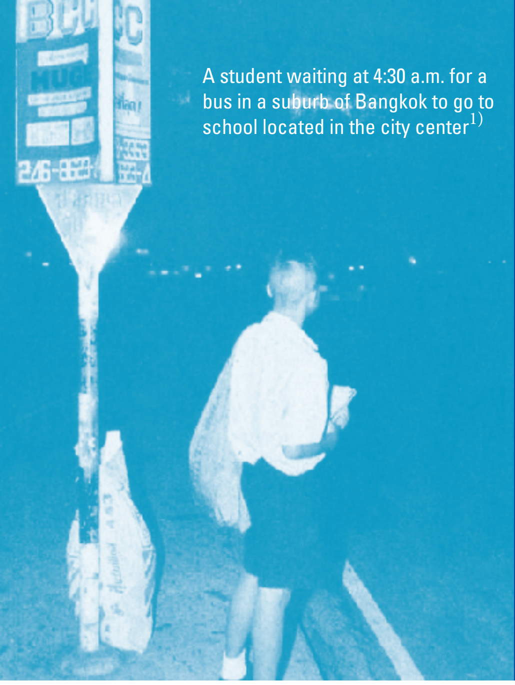
In the mid-1990s, the Japanese airline industry moved from being non-competitive to being competitive, and ease of market entry and pricing deregulation were promoted. The result was an influx of new operations in the industry, including even new operations by existing airline companies, accompanied by diversification of pricing and services. The Japanese airline industry is still not yet a true contestable market, however, due to congestion at airports such as Tokyo's Haneda Airport preventing free market entry. In such cases, the role of public entities is still large in regard to issues such as dividing new airport slots among airline companies.

References

1) Mishan, E. J., and E. Quah. 2007. *Cost-Benefit Analysis*. 5th edition. Routledge.
2) Brent, R. J. 1998. *Cost-Benefit Analysis for Developing Countries*. Edward Elgar.
3) Dinwiddy, C. L., and F. J. Teal. 1996. *Principles of Cost-Benefit Analysis for Developing Countries*. Cambridge University Press.
4) Nurkse, R. 1961. *Patterns of Trade and Development*, mimeo, 1959. Blackwell.
5) Hirschman, A. O. 1958. *The Strategy of Economic Development*. Yale University Press.
6) Bamford, C. G. 2006. *Transport Economics*. Heinemann.
7) Transport for London. 2014. "Transport for London Congestion Charge Factsheet." *Transport for London*. Accessed September 25, 2014. https://www.tfl.gov.uk/cdn/static/cms/documents/congestion-charge-factsheet.pdf.
8) Baumol, W. J. 1982. "Contestable Markets: An Uprising in the Theory of Industry Structure." *American Economic Review* vol. 72, No. 1.

Recommended Reading

1) Boardman, A., D. Greenberg, A. Vining, and D. Weimer. 2013. *Cost-Benefit Analysis: Concepts and Practice*. 4th edition. Pearson.
2) Vickers, J. and G. Yarrow. 1995. *Privatization*. MIT Press.



A student waiting at 4:30 a.m. for a bus in a suburb of Bangkok to go to school located in the city center[1)]

Final thoughts

Resilient mobility society

Before concluding the Theory section, this chapter will explain "traffic resilience" as a concept essential for transportation during ordinary times as well as during emergencies. Here, three important levels in transportation will be kept in mind: technology, systems, and society.

Besides denoting the ability to recover or stabilize, "resilience" also means flexibility. To define resilience in terms of moving people or objects, a resilient object would be one on a tightrope that, whenever it is shaken or pushed to the side, will always come back to its original standing position. In tightrope walking, balance can be restored against a certain amount of swaying if there is something like a balancing pole to act as a stabilizer. If the tightrope walker stops, however, the balance maintained while walking may be lost and the rope may start swaying. Sustainability, which is used in contrast to resilience, is conceptualized as the ability to use one's last step as support in taking one's next step forward, without stopping. The basis for sustainability, the ability to take that step forward, could not be formed without resilience—the stability of ground to stand on Fig. 1. In this sense, instead of defining resilience as a

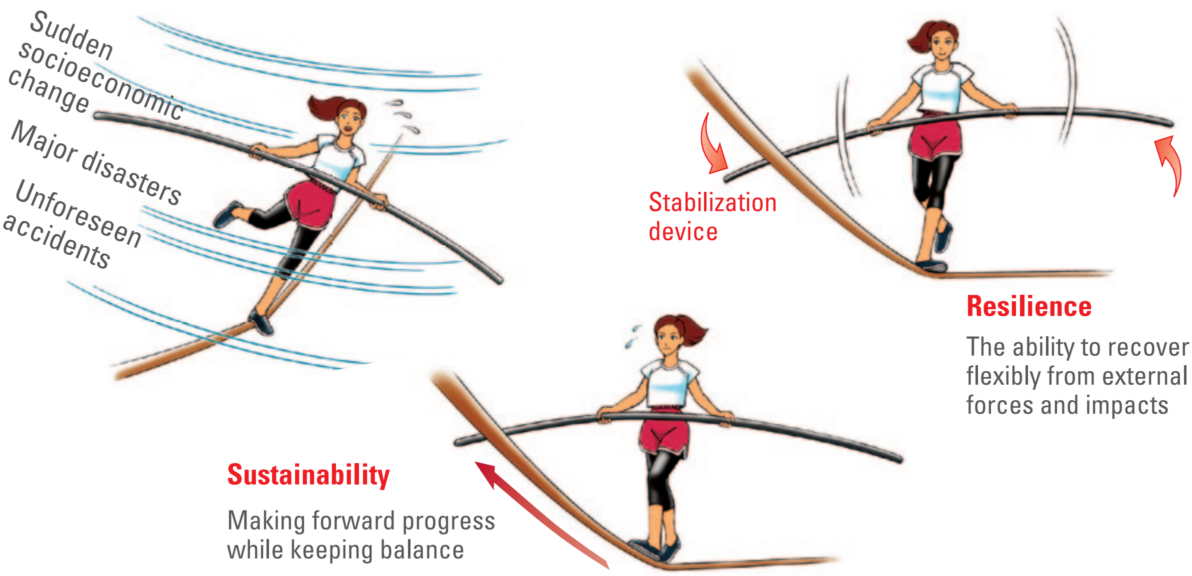


Figure 1. Resilience and sustainability

special quality for times of disaster or emergency, resilience should be defined as a prerequisite for accumulating steps forward each day, and realizing a safe and sustainable mobility society.

Below, I introduce the connotations of resilience learned through my own experiences in a developing country in Asia. Factors involved in realizing a resilient mobility society are also discussed.

Non-resilient traffic situations

I visited Bangkok and stayed with a friend of mine in the 1990s. During my visit, there was an incident where the school bus my friend's children rode had not arrived by 8:00 p.m., even though it usually arrived by 5:00 p.m. We were all worried that the bus had been involved in some sort of accident, but it turned out it was just stuck in traffic.

In those days, I was involved in the Advisory Committee of JICA for the Study on Improvement Plan for Railway Transport in and around the Bangkok Metropolis in consideration of Urban Development in the Kingdom of Thailand (1992–96), which was organized by the Japan International Cooperation Agency in order to alleviate the huge traffic jams in the city of Bangkok by using the railway system as a cornerstone. Having been appointed as the chair of the project, I was astonished that the city's traffic congestion was extraordinary. A survey conducted at the time revealed that the percentage of people who spent more than 8 h a day commuting in the Bangkok Metropolitan Area had reached 10%. Although I did not know the term "resilience" at that time, when I learned the word, I came to realize that the traffic congestion in Bangkok had been totally *non-resilient*.

A group of Japanese and British researchers attempted to remedy the congestion in Bangkok using traffic signals, but soon ran out of options because of the reality of the situation, where the tail end of vehicle queues at one traffic signal would enter through the intersection at the next traffic signal. Once vehicles entered an intersection for a right or left turn, they could no longer move and stayed at an oblique angle to other traffic lanes. This is gridlock, meaning the paralysis of the grid-like system of roads. A traffic jam with no moving vehicles spreads through the entire network of intersecting streets. As soon as a traffic jam started at one intersection, vehicles at the next intersection also came to a stop, and this spatial propagation affected other intersections one by one. From the perspective of the system, a microsociological phenomenon at individual intersections transforms into the macrosociological phenomenon of hypercongestion. The phenomenon then propagates throughout the entire road network and paralyzes it. This is similar to dysfunction in one area of the body spreading throughout the body and incapacitating the entire regulatory network.

In terms of time, hypercongestion is characterized by an increase in travel time and in the size of its fluctuations because, for example, a certain distance that required 2 h to travel yesterday may require 4 h today. When considering traffic resilience, it can be said that traffic is resilient if travel time fluctuations converge within a certain range. However, when fluctuations extend outside of this range and cause the traffic to become divergent and lose the ability to recover, this can be regarded as non-resilient traffic. Non-resilient traffic becomes extremely unstable, making prediction of travel times impossible, and affects not only the transportation system, but also urban activities and the economy. For example, it may become impractical to make multiple business appointments for the day, and only one meeting may be scheduled for the morning or afternoon. I witnessed how the resilience of society was lost because of the adverse effects of traffic congestion.

Establishment of a multidisciplinary organization to address problems

Around 1992, the State Railway of Thailand (SRT) was in a very weak position. In developing countries including Thailand, the railway system was considered to be a dirty transportation system used by only people at the bottom of the social strata. Because of daily delays, railway systems were not trusted and most government officials involved in decision-making used chauffeur-driven cars and had no interest in railways. Consequently, even when the significance of railway systems was explained at the National Railway, which should be the center of the railway system, the idea could not reach the decision-making officials.

The project we undertook aimed to revive the railway system within 200 km of Bangkok. However, we could not access or use the land under the railways in the central part of the SRT network, which included 15 km of the Northern Line and 30 km of the Eastern Line, because the land use rights were held by the Hopewell real estate company, based in Hong Kong. Because of this, we decided to embark on the following two things. First, to move the project forward, we established a multidisciplinary organization. Instead of attempting to proceed through only the SRT, we made the steering committee an interdisciplinary body spanning various government ministries, and asked Administrative Vice Minister Sansern of the National Economic and Social Development Board of Thailand (NESDB) to serve as the committee chair and Vice President of the National Railway to serve as the vice committee chair. We also requested the participation of officials involved in land utilization or transportation, such as those in the Housing Agency and the Ministry of Transportation.

The NESDB was an organization similar to the then Economic Planning Agency of Japan, yet had authority equivalent to that of the Department of the Interior. We comprehensively explained to the committee members how significant the railway system was. At that time, Bangkok already had a population of 6 million and the entire Bangkok Metropolitan Area had a population of 11 million. Bangkok was a megacity that needed to use the railway system to resolve the basic issue of transportation demand. We tried to make the committee members understand that if only roads, but no railways, were used to address the problem, the transportation demand would not be controlled unless the majority of the metropolitan area was transformed into roads. Amid these efforts, the Bangkok Post reported the concern of King Bhumibol regarding the massive traffic congestion in Bangkok, and this generated a much needed tailwind and changed the minds of the committee members.

In a series of related events, the Office of Commission for the Management of Land Transport (OCMLT) was held in 1993. Although traffic-related issues were originally under the jurisdiction of the Ministry of Transportation, they were placed under the jurisdiction of the Prime Minister to make all government ministries responsible for addressing traffic-related issues. Under the new system, an interdisciplinary organization was developed, for which Professor Kumropluk, of Urban Planning at Kasetsart University, became the appointed deputy director. In this way, the organization was entrusted to professionals in urban planning who had a holistic view of the entire city, which became advantageous later on.

Another key to solving the traffic congestion was taking the time to continuously and persistently make all the committee members understand the usefulness of rail transit systems through the whole period of the JICA's study. In 1999, 3 years after the final report meeting for the project in January 1996, the first Skytrain line commenced operation. The development of intercity train tracks had been a long-sought plan of Governor Chamlong and Deputy Governor Winai since the 1990s. We made some materials to illustrate to the passengers of the elevated line that they would be able to look down at the traffic congestion below before returning home between 6–7 p.m. and enjoying dinner with their families. At the time, such a lifestyle was absolutely impossible, as it took 4 h to go home after work. However, we continued to show such a lifestyle as the future lifestyle of Bangkok and continued to draw attention. Finally, the road to realization was opened when elevation of the Skytrain rails was completed.

Innovative attempts to create novel travel styles, habits, and culture

To increase the acceptance of new transportation technologies and systems, it is important to persuade people exhaustively as well as allow them to actually experience the new transportation technology so they may go on to talk about it. One of my friends, an assistant to the president of Chulalongkorn University, gave great praise to the reduction in her commute time from 1–2 h one way by car to 15 min by Skytrain.

One of the factors that contributed to the creation of the novel style of travel on Skytrain was the flat fare of 30 baht. There was a debate over whether the fare should be 20 or 30 baht. Some raised a concern that the fare of 30 baht would deter low-income people from taking Skytrains, but ultimately the fare was set at this level. As a result, white-collar workers became the main users, showing that we were able to attract middle-income people, who would have otherwise bought a car, to commute via the clean and comfortable railway system. Furthermore, the social status of the users helped to raise the position of railways in the society. The development of the Skytrain system was followed by the development of subways and the Airport Rail Link (maximum velocity, 160 km/h) to Suvarnabhumi Airport, resulting in a total of 84 km of new urban railways in the 13-year period from 1999 to 2012.

Around the same time as the shift in transportation mode brought about by these measures, the construction of urban highways began parallel to the railways. Although the average speed on the streets in Bangkok was approximately 20 km/h in the mid-1980s, it was reduced to 6 km/h, the same as walking speed, in 1992. Today, the speed is back to near 16–17 km/h. Last year while speaking with the vice president of the public enterprise for the Thai underground subway system, I was pleasantly surprised to hear "two whole hours", as in, "it took *two whole hours* to get home from Suvarnabhumi Airport!" A travel time that had once been an inconceivably short had come to be seen as unacceptably long.

Three factors played a role in improving the speed on the streets of Bangkok. The first factor was, needless to say, the urban railway systems, including Skytrain, along with the measures such as the fare system for keeping the infrastructure clean. The second factor was the simultaneous development of the urban highway system. The third was the construction of the outer beltway. The urban highway and railway systems absorbed traffic from the roads, and at the same time, the beltway absorbed the through traffic.

In hindsight, traffic resilience was improved by the improvement of systems. At that time, foreign capital was flowing out of Bangkok into Kuala Lumpur, Jakarta, and Singapore due to the fear of non-productivity caused by the hypercongestion. However, due to the improvement of the congestion, foreign capital has started to return to Bangkok. In addition, by enhancing the resilience of the transportation system, the economy recovered as well. The return of industry has increased the size of the overall economic pie, which has gradually increased the distribution of income and thus mean income.

The relationship between transportation systems and society should not be oversimplified. Although questions remain as to how thoroughly the governments of Thailand and the Bangkok Metropolitan Area considered the effects of this plan, the goal was realized only because of the development of the interdisciplinary organization that enabled more fruitful discussions.

Following the development of the Skytrain system in 1999, the subway system and the Airport Rail Link were established one after another. It was fortunate that Professor Kumropluk, who was integral to the project's success, became the deputy director of the interdisciplinary organization, and it was also greatly helpful that the other personnel we supported were able to become the organization's think-tank and change the minds of others from the inside.

Resilience and sustainability of the mobility society

Resilience at each time point determines the sustainability of the steps to be made over time. Compared with resilience, which is a stage in short-time flows, sustainability is close to the concept of a long-term stock and is defined as sustained dynamic stability over a long cycle of 20–30 years. This is not to say that one of them is more important than the other; both are equally essential.

For example, automobile companies are the major players in transportation technology and their employees know automobiles very well, but often the companies do not comprehend the overall traffic situation. This is fatal. It is important to have the proper attitude when considering which frame should be used to understand traffic-related issues and what common ground is used for this understanding. In this chapter, mobility society has been examined on three levels: transportation technology, systems, and society. However, the key point is the kind of common mindset that the people who develop techniques and methods use to view the mobility society. It is not simply about social responsibility; breadth is needed to cross-sectionally share knowledge and awareness. I believe that the founder of the IATSS, Mr. Soichiro Honda, had keen intuition about transportation-related issues, including how to maintain resilience and sustainability for the entire mobility society. The IATSS reflects the spirit of its founder and is of great significance as it continues on as an organization entrusted with these great responsibilities.

Reference
1) *Bangkok Post*, September 4, 1993.

Practical application projects for reference
Realization of earthquake disaster crisis management and a society with safe and secure transportation: 208–211

PRACTICE

A land utilization framework and transportation system for declining population

1. Background and goals

We investigate the question of whether future generations will be able to inherit Japan's current urban landscape.

Most of Japan's current urban landscape was created in the latter half of the twentieth century and particularly rapid and substantive improvements were made to public-sector social capital such as rivers, roads, ports, airports, and railways. In the latter half of the 1980s, these improvements began to be made with apparent consideration if they are inheritable into the future under the concept of civic design.

In contrast, when we turn our eyes to built-up landscape, it has become a common sense that private sector buildings assumed to be replaced in every generation. Japanese housings, even including those made from concrete, have an average lifespan of only around 30 years. This indicates that they are regarded as consumable-durable goods to be demolished and rebuilt three times per century. Moreover, almost all buildings are designed in isolation, with no consideration of harmony with their surroundings. As a result, the visual appearance of individual street blocks—which are the units at which collaborative landscape creation can be realized—tends to be somewhat unimpressive and even shabby. Most cities, therefore, have not been successful in creating urban stock to be inherited to the future generation.

Another shortcoming is that greenery has not been emphasized in urban areas. Low-rise detached buildings have been allowed even near city centers to result in crowded downtown areas with little green open spaces. Major transportation facilities divide spacious green areas, and low-density built-up areas spread out to the suburbs. Particularly since the 1970s when increased incomes allowed the average household to purchase automobiles, urban areas have encroached beyond the reach of railways and further reduced green areas.

Japan currently faces issues of economic maturity and recession accompanying population decline and aging. This project focuses on whether such unregulated land use are acting to significantly degrade quality of life in Japanese cities.

In search of hints as to which direction Japan should proceed in the future, we introduce some of the results of our on-site investigations regarding cooperative land use and transportation systems in

Project Leader: Yoshitsugu Hayashi
Professor and Director, Education and Research Center for Sustainable Co-Development, Graduate School of Environmental Studies, Nagoya University

Western cities where economic development has preceded one step ahead of Japan's. As a domestic model, we also introduce the corridor-type land-use system being introduced in Utsunomiya City as an accompaniment to its light rail transit system. The outcomes of this project have been published in a book.(1)

2. Research content

2-1. Compact, urban, green (Munich, Germany)

To achieve sustainable economic, social, spatial, and regional development while protecting the environment and minimizing resource consumption, Munich has been advocating strategies of compactness, urbanity (fusion of diversity), and greenness (greenery and global environment) for urban area formation.

Munich has established policies limiting new development to the areas within walking distance of train stations, gradually leading to the realization of compact urban districts. This has resulted in a concentration of large-scale development along railways on the west side of the central station. Contracts are formed such that profits from development are evenly shared among developers (landowners), railway operators, and the local government, institutionalizing sufficient infrastructure development through value capture.

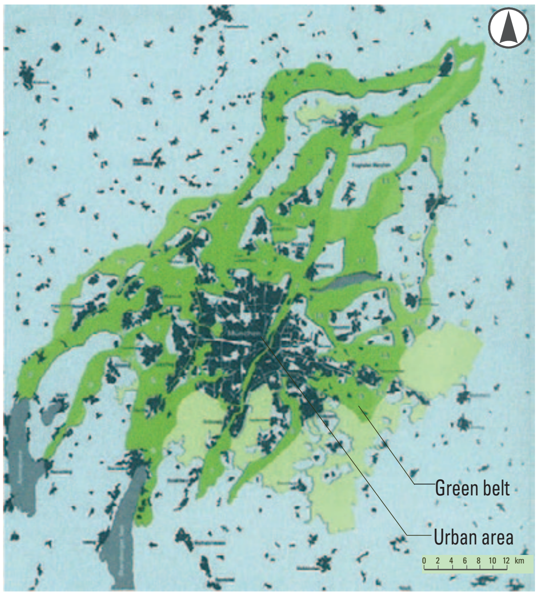


Figure 1. Land-use planning in Munich

In pursuit of realizing urbanity, new development must also devote a certain amount of floor-space to residential space, not only improving compactness but also creating a city in which diverse people can live. Furthermore, local policies require a wide range of rent settings, thereby providing a mix of socially diverse people and forming a city that can pass on an exceptional regional culture.

Lastly, Munich has policies to realize greenness, such as its regulations requiring the development of green areas along railways and accommodating the surrounding urban areas.

2-2. Integration measures for land use and transportation to enhance location efficiency (U.S. cities)

Transit-oriented development (TOD)(2) gave rise to a great movement in the United States in the latter half of the 1990s. TOD is not simply a method of compact urban development formed around public

---

(1) Hayashi, Yoshitsugu, Kenji Doi, Hirokazu Kato, and International Association of Traffic and Safety Sciences, eds. 2009. *Toshi no kuoritei sutokku: Tochi riyo, ryokuchi, kotsu no togo senryaku* [Quality Stock of Cities: Integrated strategy of land use, green space and transportation]. Kajima Institute Publishing. (in Japanese)

(2) TOD emphasizes development of public transportation nodes as the axis along which urban areas are formed, and induces development around these nodes. This allows economic activity to occur within walking distance of transportation nodes, placing focus on lifestyle opportunities and enhancing quality of life.

Figure 2. Examples of TOD implementation in Prince George's County, Maryland, USA

transportation. Well-known features of TOD include urban development within walking distance of transit stations, high residential density, and high functional diversity, but underlying this a geographical layout are a variety of systems that aim to improve quality of life and social justice.

One such system is location-efficient mortgage (LEM),(3) a policy tool for supporting home acquisition in areas within walking distance of public transportation by creating benefits given to residents who save personal and public transportation costs. This allows escape from over-reliance on automobiles. Discount train passes are also offered to increase utilization of public transportation.

This has changed the definition of richness from one based on income to another based on time. The dissemination of TOD schemes among US cities reflect change in citizens' sense of values. Such a change is also necessary in Japan, particularly when one considers future constraints on public financing, the environment, and consensus formation.

2-3. Intensive land use for transportation networks and corridors (Utsunomiya, Japan)

Realizing TOD necessitates enhancement of the public transportation systems as its axes. Light rail transit systems (LRT) have been attracting international attention as methods for low-cost rapid transit. LRT systems have been introduced in Japan in recent years, significantly changing strategies for urban land usage.

Utsunomiya, having a population of 500,000, is a core city in the northern Tokyo metropolitan area that has experienced significant postwar development as an industrial city. However, it features an extremely high level of automobile dependency, which has resulted in sprawled residential areas in its

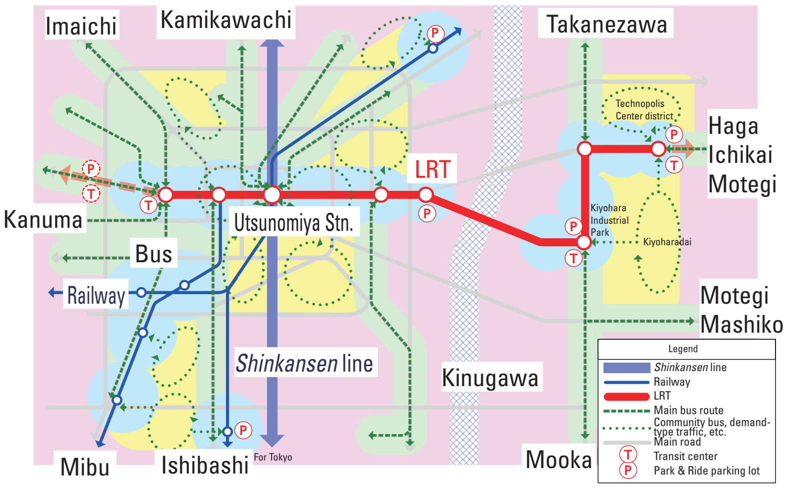


Figure 3. LRT implementation plan (Plan for Securing Daily Life Transportation) in Utsunomiya, Japan

---

(3) LEM is a coordinated housing and transportation policy system that promotes the realization of TOD. To create benefits for residing in areas accessible by public transportation, savings on automobile-related costs such as fuel, parking, and road tolls are calculated on a by-area basis, and the amount saved is included when determining levels of homebuyer support.

suburbs, diffusion of urban functionality, and progressing hollowing out of the city center.

After the planned introduction of LRT has taken place, public transportation service in Utsunomiya will be divided into four areas based on urban structure, with service provision adopted according to the conditions of each area. Utsunomiya aims to create a public transportation network servicing the entire region through seamless coordination of the bus network with its core LRT system. In the urban center, automobile traffic will be curbed, while pedestrian and bicycle traffic will be developed and emphasized. Introduction of LRT will also involve the conversion of major roads into transit malls, securing walkable spaces in commercial areas to enhance pedestrian movement. At the same time, urban development will aim to revitalize commercial districts along placed LRT routes by introducing LRT in conjunction while also carrying out redevelopment projects. Lastly, composite development, such as the creation of an attractive urban landscape and urban residential areas, will be required in Utsunomiya, in addition to the city's planned redevelopment projects.

3. Conclusions

In this project, we refer to the continual foundation of twenty-first century land and cities as a quality stock that combines building clusters, green areas, and transportation systems. We have presented a vision of urban retreat and reformation based around the formation of high-quality building clusters with a unified look and of green area–public transportation corridors in a book *Toshi no kuoritei sutokku* [Quality Stock of Cities] (Kajima Institute Publishing).(1) This goes beyond the simple ideal of a compact city to incorporate universal social goals and a vision featured on local societies, and provides specific methods for realizing this vision.

Maintaining quality of life in the future will require coordination of integrated urban landscapes of transportation, buildings, and green areas. This strategy will not be implementable if the future economy declines too far; thus, this strategy should be taken as an urgent national priority.

4. Future outlook

The creation of quality stock that unifies building groups, green areas, and transportation systems can reverse urban structures, thereby lowering cost of living and improving the environment in the inner city. The result is development of the requirements for compacting and shrinking cities smartly, which constitutes necessary activities for stopping the "slumification" of Japanese cities and allowing the survival of the next generation.

Quality of mobility required for super-aged cities

1. Background and goals

To enhance the quality of mobility in cities, it is necessary to construct a hierarchical network consisting of a fast mobility layer that supports rapid transportation between hubs, and a slow mobility layer that supports low- and medium-speed transportation within hubs and towns. The needs for a safe and comfortable slow mobility layer will likely be particularly important in the context of a super-aged society, and the development of not only individual means of transportation but also the road environments containing them will be vital. Ultra-compact, low-speed, short-range vehicles have been developed in recent years to meet these needs, and some locations in the United States and elsewhere are using space opened up by "road diets" (reducing the number/width of automobile lanes) to create travel space for ultra-compact vehicles and bicycles. Such cases show a sense of road space utilization that is being fostered by a new mode of transportation developing between pedestrians, cyclists, and automobiles. This can be taken as a suggestion of the possibilities for co-development of transportation methods, space, and infrastructure in a super-aged society.

In a project this year, we analyzed changes in values related to quality of mobility. Then we carried out a pilot survey to use as a basis for anticipating future needs for slow mobility transportation methods, road spaces, and system development.

1-1. The viewpoint of this research

The idea of "slow mobility" used in this project is a new mode positioned between walking and other forms of transportation (Fig. 1). Slow mobility is a medium- to slow-speed transportation method that supports walking and emphasizes ease of getting off vehicles, rather than getting into them. Furthermore, it promotes human exchange and can therefore be viewed as a social system that supports and improves regional vitality and quality of life. As Fig. 2 shows, the concept of "co-mobility" is defined here as the combining of community and mobility by tying together not only places but people as well.

The ultra-compact vehicles that hold promise for use in slow mobility can be grouped under current law into four types: walking aid devices, bicycles, mopeds, and mini-cars. In this project, we focus on the use of electric assist bicycles and moped-type micro-electric vehicles (hereinafter, micro-EVs).

Project Leader: Kenji Doi
Professor, Department of Global Architecture, Graduate School of Engineering, Osaka University

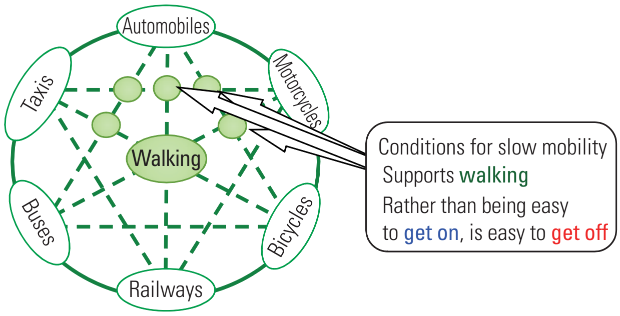


Figure 1. Positioning of slow mobility in urban transportation

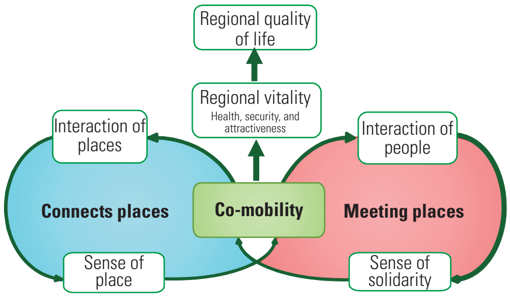


Figure 2. The co-mobility concept

2. Research content

2-1. Pilot survey in Mino, Gifu

The city of Mino (pop. 23,000) in Gifu Prefecture has long aimed at town planning that supports cycling, but cycling has not caught on due to its hilly terrain and the advancing age of its residents. In this study, we proposed a co-mobility strategy for Mino's slow life and cycling city concepts, and performed a pilot survey aimed at its realization.

Figure 3. Micro-EV decorated in Mino-produced Japanese paper

In the study, electric assist bicycles and micro-EVs were loaned to participants. GPS tracking and participant journaling were used for monitoring daytime and nighttime usage to investigate attitude changes, behavior, and the potential for lifestyle changes. The focus of the experiment was not to promote slow mobility, but to investigate how subjects would select transportation modes when presented with five options (walking, cycling, riding electric assist bicycles, using micro-EVs, or driving automobiles), and to examining changes in out-of-home behavior patterns.

The results of the experiment confirmed that offering these five modes of transportation resulted in a substantial widening of choices, thereby resulting in more frequent opportunities for out-of-home activity and a lowered reliance on automobiles. For example, the frequency of using personal mobility vehicles such as micro-EVs and electric assist bicycles for commuting or business activities reached the same combined values as that for automobiles. This raises the possibility that increased spread of personal mobility vehicles might lead to changes in mobility styles in regional cities that are currently experiencing over-reliance on personal car ownership.

Comparing usage frequencies of the five modes by distance traveled (Fig. 4), it is apparent that micro-EVs and electric assist bicycles were frequently used within a few kilometers distance, and thus that developing environments of usage space within that range is key to the spread of personal mobility.

To hear the voices of also from a wider range of residents instead of just the experimental subjects,

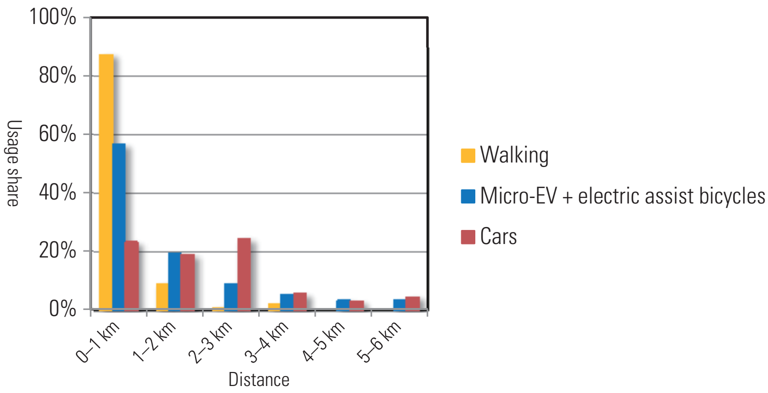


Figure 4. Usage of transportation modes by distance in the pilot survey

a workshop was held during the pilot survey, which provided an opportunity for government and citizens to come together to think of ways in which existing roads could be used to expand the usage range and opportunities for personal mobility. Various opinions were shared, such as the need for reconsidering not only transportation methods but also the structure of cities and road infrastructure, as well as the need for reducing the number of automobile lanes ("road dieting") to allow space for personal mobility. We also proposed community buses and other specific forms of co-mobility that provide meeting places to residents, connecting methods of public transportation and personal transportation.

2-2. Pilot survey in Takamatsu, Kagawa

A running test was then performed in downtown Takamatsu city, in which a road diet was implemented to create bicycle lanes, with the goal of investigating the influence of slow mobility on in-town travels. Takamatsu was selected for this experiment because Mino has few commercial or public welfare facilities in its city center, complicating measurement of the effects on travels, and furthermore because it would have been difficult to create slow mobility running spaces within the timeframe of the study.

In the experiment bicycle lanes were positioned as "slow mobility" lanes, and we verified the ease, safety, and potential for co-existence when micro-EVs shared lanes with bicycles (Fig. 5). The results were as follows:

(1) Bicycles and micro-EVs can travel together without conflict at speeds up to around 20 km/h.

(2) Implementation of simple road diets such as the establishment of slow mobility lanes lowered

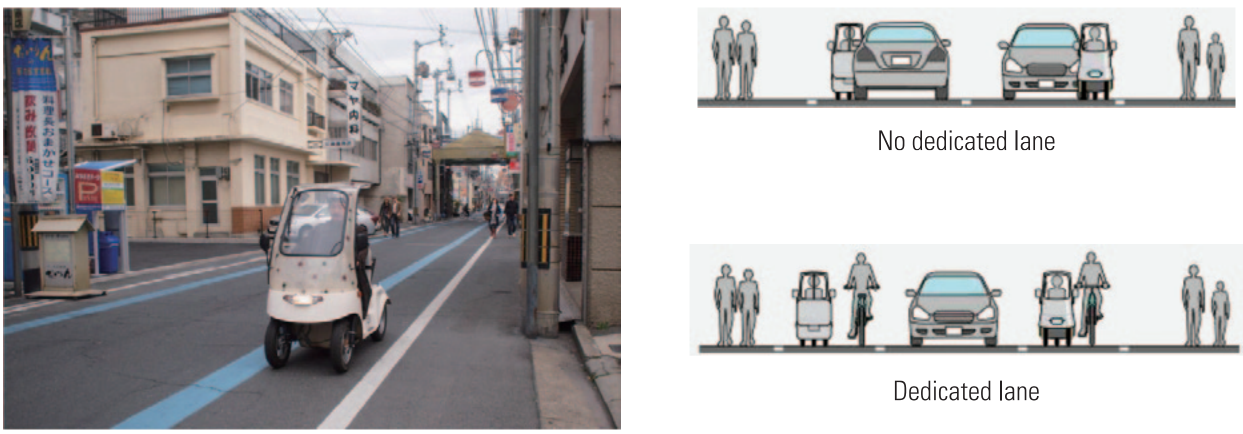


Figure 5. The slow mobility lane experiment in Takamatsu City

automobile running speeds by 3–8 km/h, reducing the speed difference between vehicle types.

(3) Safety was improved in areas where slow mobility lanes were established (i.e., where road dieting was implemented) over areas where they were not.

3. Conclusions

From the results of our investigation of changes in values regarding quality of mobility and from our comprehensive investigation of super-aged society-related factors, including activity needs and desires for improvement to transportation, we found a definite trend toward safety, health, and the environment, and furthermore found that such value changes manifested needs for road diets, speed reduction, and slow, personal forms of mobility. The results of pilot surveys suggest that providing such new methods of mobility has the potential to change mobility styles in regional cities with a limited selection of transportation modes, and they confirm the utility of slow mobility lanes as a way of developing shared running space.

4. Future outlook

Developing countries in Asia and other regions require methods of traffic reduction on the premise of traffic with a variety of vehicle types, including motorcycles. The co-mobility strategies proposed in this project, which combines road dieting, speed reduction, and slow, personal forms of transportation, are likely to provide important clues regarding methods for safe, sustainable transportation in other countries with various traffic situations.

Urban development from parking lots considering inner-city parking density

1. Background and goals

Automobiles are now a vital means of transportation for the elderly and persons with disabilities, to the extent that in rural parts of Japan, there are over 0.8 automobiles for person. Every automobile requires around 15 m^2 of parking space, both at the point of departure and at the destination; this is approximately the same amount of space per person in an average Japanese residence. As a consequence, parking spaces in many cities currently occupy approximately 20–30% of the inner-city surface area. In a typical planned city, parks occupy approximately 3% of the surface area and roads approximately 25%. Accordingly, the area required for parking cannot be ignored in urban planning.

2. Research content

In this project, emphasis is placed on three "D"s and one "M." The first "D" is "density", which refers to how many parking spaces are needed in inner cities. The second "D" is for "disposition," which refers to where parking lots should be placed. The third "D" is for "design," which refers to specifically what kind of parking lots should be provided. The "M" in this study is "management", which refers to how to manage parking lots. Each of these four aspects must be carefully considered. This paper presents an overview of research regarding density, the most fundamental of the four points described above.

2-1. Level of parking needed in urban areas

To investigate the required scale of parking lots needed in inner-city areas, we performed on-site investigations in Japan, the United States, United Kingdom and Germany (Fig. 1). We found that the cities with the most parking spaces available were Houston and Dallas in the United States, which had over 200 spaces/ha. The locations with the least parking were central London and Westminster.

As for Japanese cities, downtown Yokohama, Shibuya, Yokosuka, Odawara, Shinjuku and Tachikawa have approximately 50–70 spaces/ha. There were slightly more in Chiba, Kofu and Saga, which had approximately 75–80 spaces/ha, and relatively new towns located some distance from Tokyo such as Chiba New Town and Tsukuba New Town had around 100 spaces/ha, thanks to the numerous large-scale parking facilities in those areas. Note that most locations have approximately 60–70 spaces/ha, which is thought to be because local government ordinances regarding parking spaces in Japan mandate a nearly identical level.

Project Leader: Takayuki Kishii
Professor, Department of Civil Engineering, College of Science and Technology, Nihon University

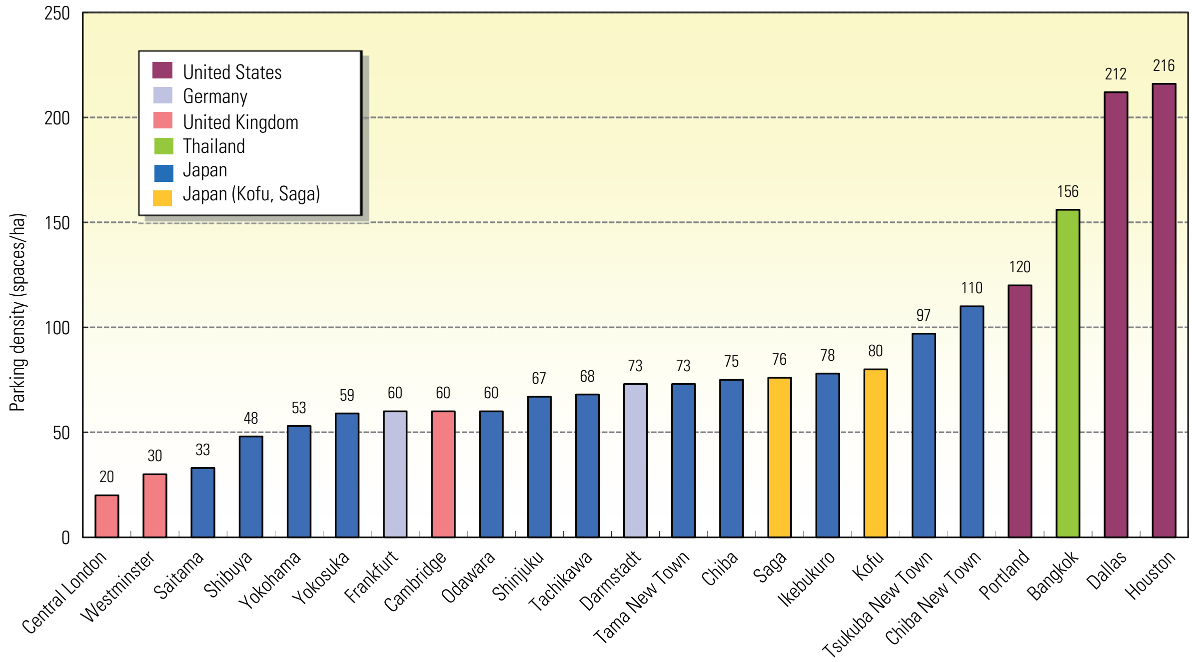


Figure 1. Parking density
Japan: Designated parking development districts;
USA: Inner-city business improvement districts; Europe: Inner loop areas
(Locations that clearly seem to be privately owned garages are excluded)

2-2. Comparison of local government regulations regarding parking spaces

The primary reason for the situation in Japan is established by local government ordinances regarding parking spaces. Table 1 shows an international comparison of similar local government regulations in other countries. Houston, which has the largest number of parking spaces, has established requirements for a minimum number of available spaces. The parking requirements in downtown Houston are on par with those of suburban shopping centers (around 200 spaces/ha), and furthermore specify that at least 75% of parking spaces should be provided on site, meaning that there are ample parking spaces even in inner-city areas.

Among the areas studied, London has the fewest parking spaces. It places an upper limit on the number of parking spaces that can be created. On the other hand, Japan has established lower limits like Houston, so while there is some variation between industrial and commercial areas, requirements generally mandate 30–60 spaces/ha. Other cities examined, such as Portland, Cambridge and Frankfurt, have local government regulations regarding parking spaces that fall somewhere between those of Houston and Japan.

2-3. Parking situation in overseas cities

Differences in the laws and standards of various countries have a strong effect on their parking circumstances. We therefore next compared two cities closely associated with this project and introduce their main features below.

Table 1. Comparison of local government regulations pertaining to parking availability standards (offices, commercial)

Houston (At least 75% on site)	Lower limit	Offices Commercial		269 spaces/ha 431–538 spaces/ha
Portland (Core Area, converted as NFA = 0.6 GFA)	Upper limit	Offices Commercial		75 spaces/ha 180–358 spaces/ha
Cambridge (Within the inner-city controlled parking zone (CPZ))	Upper limit	Offices Commercial	Within CPZ 100 spaces/ha + disabled parking Disabled parking only	Outside CPZ 250 spaces/ha + disabled parking 200 spaces/ha
Frankfurt (FF) (Inner city, 90% cash payment)	Upper limit	Offices Commercial		286 spaces/ha 333–666 spaces/ha
Japan	Lower limit			30–60 spaces/ha
London	Upper limit			7 spaces/ha

Houston, Texas

Houston is the fourth largest city in the United States. Most of its downtown is contained within a 2×2 km area. Within that area are approximately 100,000 parking spaces, for a density of 216 spaces/ha. This is approximately the same level of parking service found in large-scale suburban retail stores. There are 90 multilevel parking garages with approximately 800 parking spaces each. There are also approximately 300 surface lots.

Portland, Oregon

Portland is a public transportation-oriented city with an approximately 2×1 km downtown area sandwiched between a river and an expressway. Similar to Houston, the streets in inner-city Portland are generally in a grid pattern, as are streets in many American cities that were planned out during the pioneer days. As a result, roads alone account for approximately 40% of land use in the downtown area. The average parking density is approximately 120 spaces/ha, a density far higher than that of Japan, despite the city's image as being highly oriented toward public transportation.

3. Conclusions

Looking at the parking situation of major cities in Japan and overseas, the density of parking spaces in highly automobile-oriented societies is approximately 200 spaces/ha, but in cities with highly developed public transportation a density of around 60 spaces/ha is sufficient. Between those extremes, public transportation-oriented American cities and local cities in Japan seem to have around 90–120 spaces/ha.

However, effort is required to maintain the density at these levels, despite the fact that the results of deriving a relational equation for standards of local government regulations regarding parking space and parking density show that insofar as standards are adhered to in local Japanese cities, this density is maintained. This is because when parking space availability follows demand, the density soon increases to 150 spaces/ha. In such cases, half of inner-city areas become devoted to parking and buildings consequently seem to exist in a sea of parking lots. Our hope is that this project will contribute to preventing such an outcome through the development of attractive, functional urban spaces.

4. Future outlook

In the major cities of Japan, even when accounting for illegal parking, there is a surplus of inner-city parking spaces. This indicates the need for a more flexible approach to local government regulations regarding parking spaces (revising basic units, establishing mechanisms for utilization of parking spaces in remote locations, providing alternative parking through cost-burden sharing, etc.) and proactive aggregation of existing parking lots. We also believe there is a need to consider drastic changes to laws pertaining to parking lots, such as by adding provisions that place upper limits on the number of required on-site parking spaces. The handling of parking spaces has a large effect on inner-city land use and thus will require greater attention in the future.

Practical optimal signal control emphasizing pedestrian road crossing realities

1. Background and goals

Currently, pedestrians do not sufficiently understand the meaning of the signals at pedestrian crossings, and as a result, actual pedestrian behavior is not necessarily the same as that assumed by traffic laws. This has been noted as one factor accounting for pedestrians not completely crossing the road by the time crossing signals turn red, affecting traffic safety and smoothness by causing complications with vehicles turning left or right.

This study is a report of an actual road experiment in which we investigate and analyze changes in pedestrian road-crossing behavior after mounting auxiliary equipment to a traffic signal that allows pedestrians to clearly understand the amount of time remaining to cross the road.

The experiment first evaluated the effect of displays indicating time remaining for road crossing by analyzing videos of an actual crosswalk. We then performed an experiment in which music by the composer Keiichiro Shibuya was played during road crossings as a method of promoting behavioral change in pedestrian psychology.

2. Research content

2-1. The effect of installing crossing signals with countdown displays

We installed crossing signals with countdown displays as shown in Fig. 1 at actual pedestrian crossings, and evaluated their effect in a pilot survey (Table 1).

Figure 2 shows changes in the ratio of pedestrians who did not complete road crossing by the time

Figure 1. Pedestrian crossing signal with countdown display

Table 1. Evaluation by pilot survey (2005)

Item	Description
Experimental intersections	Tokyo: Ginza 2-chome, Ginza 5-chome, Omori Yokohama: Honcho 1-chome, MM2
Experimental period	9 December 2005 (Friday) - (about 2 months)
Survey and observation period	Before the experiment: 18, 25, 28 November 2005 During the experiment: 14, 16, 19 December 2005
Investigation methods	Videos: 3000–8000 pedestrians at each intersection Surveys: About 100 pedestrians at each intersection

Project Leader: Masahiko Katakura
Professor Emeritus, Tokyo Metropolitan University

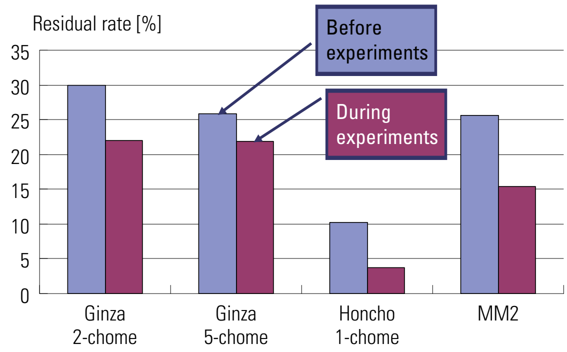


Figure 2. Effects of countdown display

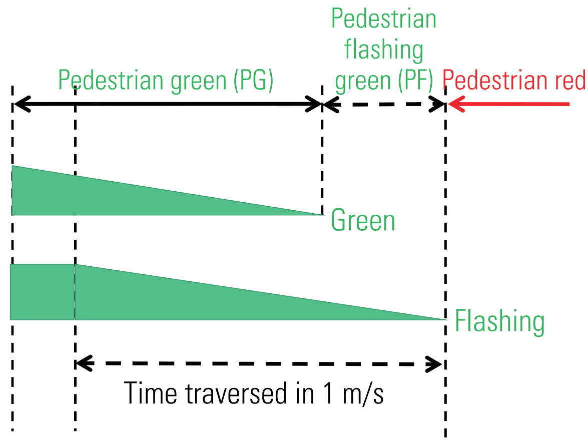


Figure 3. Green completion and green flashing completion methods

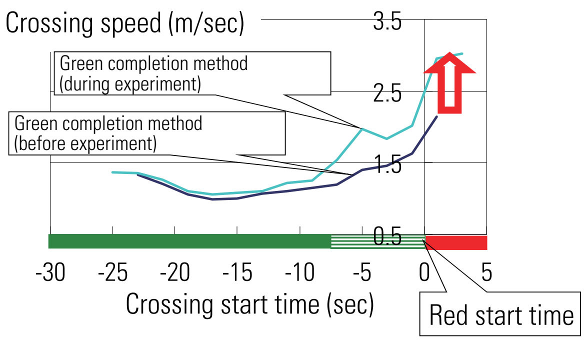


Figure 4. Change in crossing speed

the signal turned red (the residual rate) at each crossing with a countdown display. In all cases, we verified a reduction in the residual rate ranging from a few percent to as much as 10%.

Figure 3 shows the results for two types of countdown, a "green completion method" that shows the decreasing amount of remaining time and a "green flashing completion method" that shows the end of the crossing period. Both had approximately equal effects in reducing the residual rate. However, as shown in Fig. 4, the green completion method saw a rapid increase in pedestrian crossing speed during the latter half of the crossing, indicating the possibility that pedestrians feel rushed. In contrast, there is no significant difference in speed between the former and latter half of crossing when using the green flashing completion method. We presume that this is due to a reduction in the number of pedestrians who started crossing later than they should; therefore, we consider the green flashing completion method to be superior.

The results of a survey indicated that with the exception of young people (age 13 to 24 years), over 80% of pedestrians who understood the meaning of the countdown display found it helpful. We also found that placing the countdown display and the pedestrian crossing icon on separate panels (Fig. 1) increased the recognition rate of the display among pedestrians, as compared to when the icon and display were shown together.

In 2006, we experimentally installed these crossing signals at four intersections (Ginza 5-chome, MM2, Ginza 4-chome, and Tsurumi Keisatsusho-mae) for pedestrian crossings ranging from 13 to 38 m in length, conducted a questionnaire, and performed video observations of approximately 16,000 pedestrians. Results of the questionnaire performed at the MM2 and Ginza 4-chome intersections were largely positive in terms of the subjective evaluations by pedestrians. However, a statistically significant reduction in the number of pedestrians not completing road crossing by the time the signal turned red was seen only under the green flashing completion method at the Ginza 4-chome intersection; no effect was

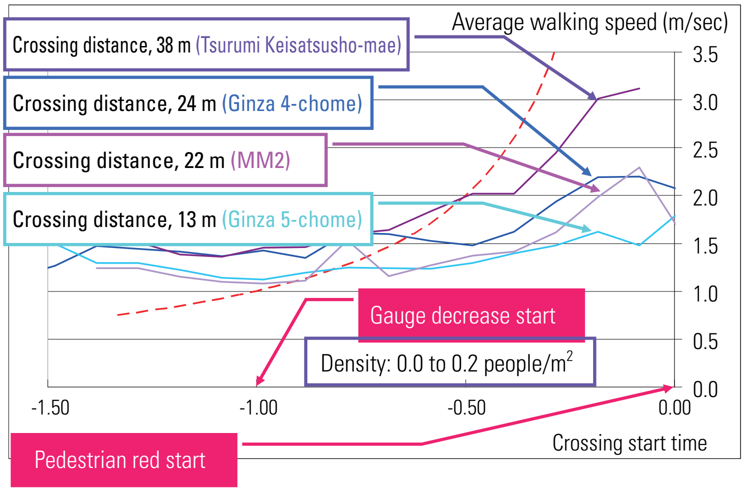


Figure 5. Crossing distance and average crossing speed (during green flashing completion)

verified at the other intersections. Yet, we were able to confirm a significant increase in pedestrian walking speed, which was proportional to the length of the crossing, in the second half of the crossing (Fig. 5).

2-2. The effect of installing crossing signals with audible cues

We installed crossing signals with audible cues, which played music when the signal was green, to investigate whether the installation changed pedestrian crossing behavior by psychologically promoting an increased crossing speed when there was little time remaining to cross, and by preventing pedestrians from initiating crossing when the green signal was flashing. The music played was composed by Keiichiro Shibuya, an established Japanese musician.

The three compositions respectively aimed at promoting a comfortable walking pace, increasing crossing speed, and warning pedestrians to prevent intrusion into the crossing. The trumpet-type speakers that can be installed into pedestrian crossing signals are very limited in the range of frequencies and waveforms they can produce, so compositions that would be easily remembered and not tiresome under these conditions had to be produced. In other words, the compositions could not simply be sinusoidal waves such as the loud tone played when a television station is off the air, but rather had to successfully employ square waves for attacks and reverberations to present a rich sound that could be clearly heard.

Table 2 shows an overview of the investigation and the obtained data. As Table 3 shows, the residual rates over all measurement times were 18.7% without music, but fell to 13.9% when the music was played, representing a statistically significant decrease. We found no difference in the time that pedestrians initiated crossing after the light turned green based on the presence or absence of music; however, there was a difference in the time that pedestrians completed crossing when music was played. This indicates that the music decreased the residual rates. As Fig. 6 indicates, this is due to an increased

Table 2. Overview of investigation and the acquired data

Observation location	Music	Video date	People crossing
Ginza 4-chome	None Yes	30 October 2007 (Tuesday) 18 March 2008 (Tuesday)	1929 1804

Table 3. Residual rate and remaining time

Music	None	Yes
Crossing count [people]	1929	1804
Residual amount [people]	361	251
Residual rate [%]	18.7	13.9
Average remaining time [sec]	5.3	4.4
Maximum remaining time [sec]	16.3	18.8
Significance		0.037

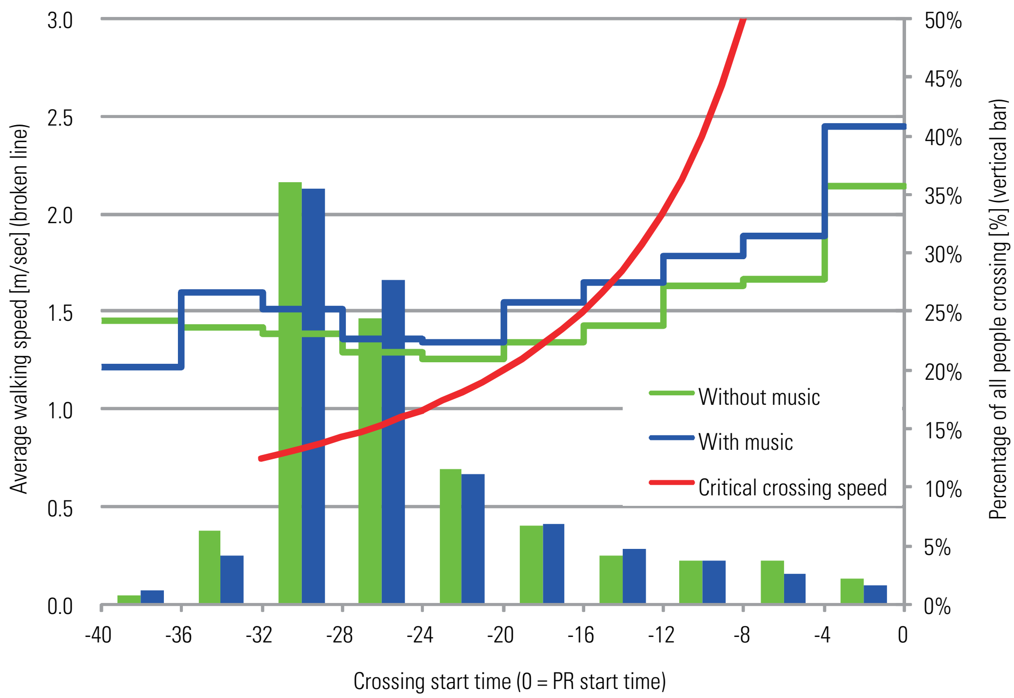


Figure 6. Average walking speed at crossing start time

crossing speed. Furthermore, we found that overall, the presence of music prevented approximately 40 people from prematurely starting to cross. We verified a similar effect in an investigation of an intersection at Shin-Yokohama 2-chome.

3. Conclusions

The pieces of music by Mr. Shibuya that were used in the present study were composed with the goal of being easy to remember and hum along to, and were clear, distinctive, and easily heard over the sound of traffic. It is likely that pedestrian crossing signals that play such music are not only accepted more easily by pedestrians, but also exhibit tangible effects of reduced residual rate and increased walking speed, providing an effective improvement to current crosswalk walking behavior.

4. Future outlook

This research indicated that pedestrian crossing signals equipped with appropriate music-playing functionality can lead to proper pedestrian crossing behavior. We hope that future studies will verify the effectiveness of crossing signals with audible music cues under a variety of road and traffic conditions and in various acoustic environments, and that the installation of such equipment at many intersections will aid efforts to improve pedestrian safety and smooth traffic.

Significant reduction of cycle length via a two-stage crossing system

1. Background and goals

The cycle lengths(1) of signals at large intersections in Japan are much longer than those in Europe. This can irritate pedestrians, who must wait a long time for crossing signals to change at intersections. In addition to intersection traffic demand, the amount of time that pedestrians require to cross intersections has a large effect on determining cycle lengths. One method to reduce cycle lengths currently attracting attention is the introduction of two-stage crossings, where a central island in the middle of a crosswalk is established and pedestrian crossing signals allow crossing independently to either side of the island (Fig. 1, 2).

In this project, we performed a pilot survey for reducing cycle lengths through the introduction of two-stage crossings. We first accumulated research through on-site investigations and simulation analysis. Based on this, and with the support of road and traffic administrators, we installed two-stage crossings at the Kasumigaseki 2-chome intersection in downtown Tokyo, Japan.

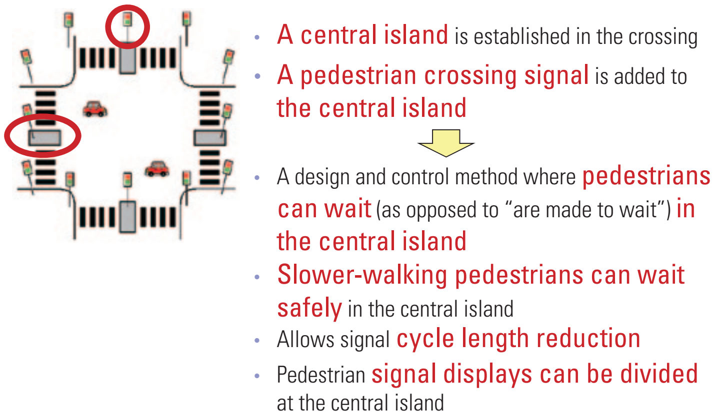


Figure 1. What is a two-stage crossing?

Figure 2. Two-stage crossings and signal display division

Project Leader: Hitoshi Ieda

Professor, Graduate School of Engineering, The University of Tokyo / National Graduate Institute for Policy Studies

(1) Signal cycle length: The time for the light on a traffic signal to cycle through green, yellow, red, and back to green. At large intersections in Japan, the signal cycle length is normally from 120 to 150 seconds.

2. Research content

In this project we (1) planned and implemented a public relations strategy, (2) performed a pilot survey and investigation, and (3) verified the effects of the experiment.

2-1. Planning and implementation of a public relations strategy

At first glance it might seem that two-stage crossings are even more inconvenient for pedestrians because the central island increases the number of times they must wait for signals, among other reasons. We therefore performed various strategic public relations activities so that users would better understand the intent of two-stage crossings.

Specifically, we created the "Easy Crossing Project KASUMIGASEKI" campaign (Fig. 3), and (1) installed explanatory panels in the Kasumigaseki subway station (Fig. 4), (2) distributed leaflets to government agencies, public offices, and pedestrians in the area, (3) created a website for answering questions and collecting opinions, and (4) advertised to the mailing lists of various organizations.

Easy Crossing Project
KASUMIGASEKI

Figure 3. The public relations logo

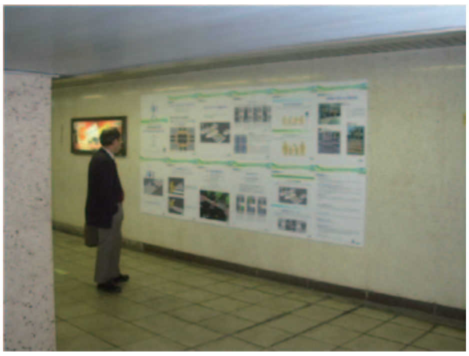


Figure 4. Explanatory panels were displayed at three locations in the station

2-2. Implementation of the pilot survey and investigation

The pilot survey was performed starting on 13 January 2009 from 10:00 to 15:00 on weekdays for one month. To ensure complete safety, we stationed a traffic guide in the central island who helped guide pedestrians (Fig. 5).

We began the experiment using a cycle length of 75 seconds (approximately one-half the normal time of 140 seconds), but as it became apparent that this caused pedestrians crossing in the counterclockwise (CCW) direction to rush, we extended the cycle length to 100 seconds from 9 February. Note that for the duration of the experiment, the cycle lengths at surrounding intersections were set to 150 seconds.

We conducted the following two investigations to measure the effects of the experiment:

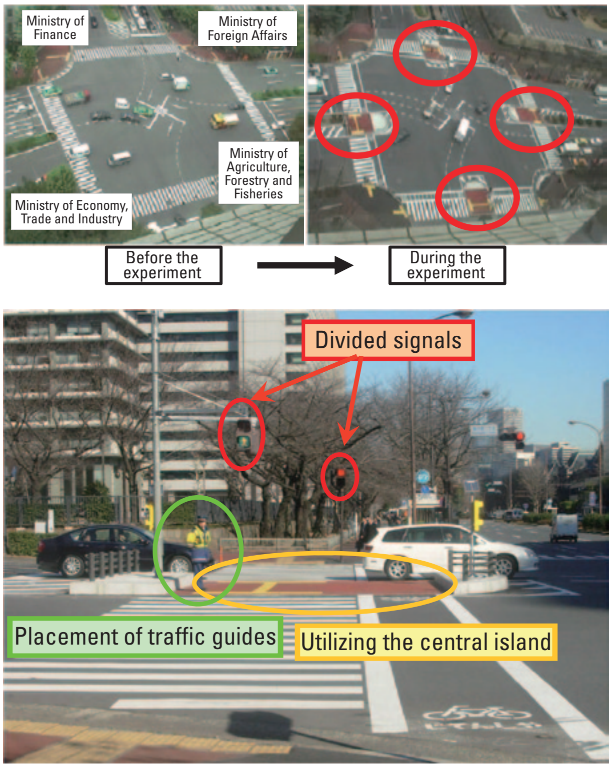


Figure 5. The pilot survey

(1) Video survey: We videotaped the crossing, and from this we measured factors such as pedestrian wait times, walking speed, how much pedestrians ignored signals, and situations when pedestrians and automobiles came into conflict.

(2) Questionnaire survey: we conducted a questionnaire survey to determine pedestrian psychology at crossings and degree of acceptance of the new crossing method.

2-3. Verification of the effect

(1) Results of the video survey

Video analysis of pedestrian behavior yielded the following results (Table 1). Note that in the analysis we weighted the spacing between arrival times of individual pedestrians, and calculated each index as a normalized uniform arrival distribution with constant density.

Table 1. Analysis results (comparison with a 140-second cycle length)

Measurement item	Two-stage crossing (75 seconds)	Two-stage crossing (100 seconds)
(1) Average pedestrian wait time	CW: 53% decrease CCW: 18% decrease	CW: 54% decrease CCW: 6% decrease
(2) Average walking speed	CW: 6% increase CCW: 26% increase	CW: 3% increase CCW: 9% increase
(3) Pedestrians in crossing after signal changes to red	CW: 3% decrease CCW: 61% increase	CW: 8% decrease CCW: 30% increase
(3)' 95th percentile walking time after signal changes to red	CW: 67% decrease CCW: 20% increase	CW: 74% decrease CCW: 12% decrease
(4) Pedestrians in central waiting island	CW: 0% CCW: 34%	CW: 0% CCW: 28%

(a) Changes in pedestrian wait times

We found that average pedestrian wait times decreased in all scenarios. Specifically, with a cycle length of 75 seconds (C75) the wait time for pedestrians crossing in the clockwise direction (CW) was decreased by 53% and that for pedestrians crossing in the CCW direction was decreased by 18%. With a cycle length of 100 seconds (C100), the CW decrease was 54% and the CCW decrease was 6%.

(b) Changes in walking speed

We next examined average pedestrian walking speed and found that with C75 there was a 6% CW increase and a particularly high 26% CCW increase. With C100, there was a significantly smaller increase in walking speed in both directions of just 3% CW and 9% CCW.

(c) Changes in the ratio of pedestrians remaining in the crosswalk and in pedestrian walking time after signal change

We also compared the ratio of pedestrians remaining in the crosswalk when the signal became red, and found that while there was a 3% CW decrease with C75, there was a very large 61% CCW increase. The CCW increase was lowered to 30% with C100. This is still not a low number, but when we compare 95th percentile values of walking time after signal change for pedestrians remaining in the crosswalk, we found that although with C75 there was a 20% CCW increase, with C100 there was a 12% CCW decrease. This indicates that with C100 pedestrians are clearing out of the crosswalk faster than with C75. When we interviewed the traffic guides regarding this, they reported that many

CCW-walking pedestrians ignored signals when the cycle length was 75 seconds, but that this was not a problem at 100 seconds.

(2) Questionnaire survey results

Responses to the questions "Were you able to cross with less waiting time than at other intersections?" and "Were you able to cross without hurrying?" showed trends similar to those found as a result of video analysis. Responses to the question "Do you think that crosswalks with a central waiting island and separate crossing signals like those used in this experiment should be applied to various other intersections?" were around 70% positive for pedestrians crossing in each direction, indicating a high level of pedestrian acceptance of two-stage crossings. However, slightly less than 40% of respondents reported difficulty understanding how to cross the two-stage crossings, indicating that this is a problem that must be addressed.

3. Conclusions

Results of the analysis of the pilot survey performed in this project indicate that cycle length reduction via two-stage crossings is an extremely effective measure for reducing automobile and pedestrian wait times and irritation. Considering that nearly 70% of pedestrians had positive feelings toward this experiment, we believe that there is a high probability that the introduction of two-stage crossings in Japan will be accepted to reduce cycle times. We note, however, that negative opinions related to pedestrian confusion were expressed regarding the new crossings. Some pedestrians would try to cross them in the usual manner, not noticing the change in signals.

In the future, it will be necessary to accumulate experience at a variety of intersections to discover methods by which two-stage crossings can be better understood, such as by changing crossing structure, adjusting the position and size of signals, changing how remaining time and wait times are displayed, or providing road lighting and voice guidance.

4. Future outlook

Since the implementation of this project, both road and traffic administrators have gained an understanding of the effectiveness of two-stage crossings, and the implementation of these systems will be considered at some locations. However, the true effect of cycle length reduction via the introduction of two-stage crossings will only be seen after the verification of network effects through their introduction at multiple locations. It will therefore be essential in the future to select locations where this method can be applied as a network, and to perform trial implementation in those areas. As we head toward the Tokyo Olympic Games in 2020, we must ensure that road intersections in Japan do not pose an international embarrassment, and that we continue to make changes for their increasingly comfortable use by both pedestrians and automobiles.

A study on the practical deployment and promotion of safe and ecological roundabouts

1. Background and goals

Countless accidents involving head-on collisions and vehicles turning against traffic occur at road intersections, regardless of whether traffic signals are in place. Even when installed as a safety measure, traffic signals do not always prevent accidents from occurring when the signals change or when drivers ignore them. Therefore, in some cases, signalization does not provide a fundamental solution to the problem. When installed at intersections with low traffic volume, traffic signals can even cause problems such as delays and increased environmental load. To search for solutions to these issues, the current project aims toward the practical deployment of modern roundabouts in Japan. As part of these efforts, the H188 Project was launched in 2009, with the following goals.

1) To conduct field operational tests in cooperation with government organizations, thereby collecting a variety of empirical data associated with introducing roundabouts to Japan and preparing an environment for their full-scale introduction.
2) To collect data on user behavior before and after the introduction of roundabouts at intersections, thereby accumulating empirical data for the advancement of technical findings related to the planning and design of roundabouts in Japan. Furthermore, to conduct quantitative evaluation of the effects of roundabouts by comparison of data before and after their introduction.
3) To perform ongoing promotional activities such as workshops and seminars for the implementation of roundabouts.
4) To propose specific plans, designs and technologies related to roundabouts, and to participate in technical planning of field operational tests. Through this, to accumulate and summarize experience with cases of roundabout conversion.

2. Research content

2-1. Analysis of user behavior through a mock roundabout on testing grounds

In the H188 Project of 2009, a mock modern roundabout was established at the Tomakomai Test Track of the Civil Engineering Research Institute for Cold Region, and technical empirical data were collected on user behavior related to designs and operational methods such as structural geometries, road signs, and markings. These data were then used to perform analysis of safety and efficiency, enabling the

Project Leader: Hideki Nakamura
Professor, Department of Environmental Engineering and Architecture, Graduate School of Environmental Studies, Nagoya University

acquisition of structural and operational knowledge.

2-2. Field operational road test at a roundabout in Azuma-cho, Iida City

In the H2292 project, the project team cooperated with Iida City in Nagano Prefecture and installed road markings and various safety devices in an existing rotary intersection in the Azuma-cho district, without changing the intersection's physical structure. Over the 42 days between November 1 and December 12, 2010, a field operational test was performed to verify the effects of structural improvements to an actual roundabout incorporating the latest design ideas (Fig. 1). There was a high degree of support from local authorities and residents regarding the structure and operation of the modern roundabout developed on the basis of the most recent technical knowledge. This furthermore allowed for verification of the safety and traffic-smoothing features of modern roundabouts on actual Japanese roads.

(a) Before the test (Photo by Iida City) (b) After the test (Photo by Highway Planning, Inc.)

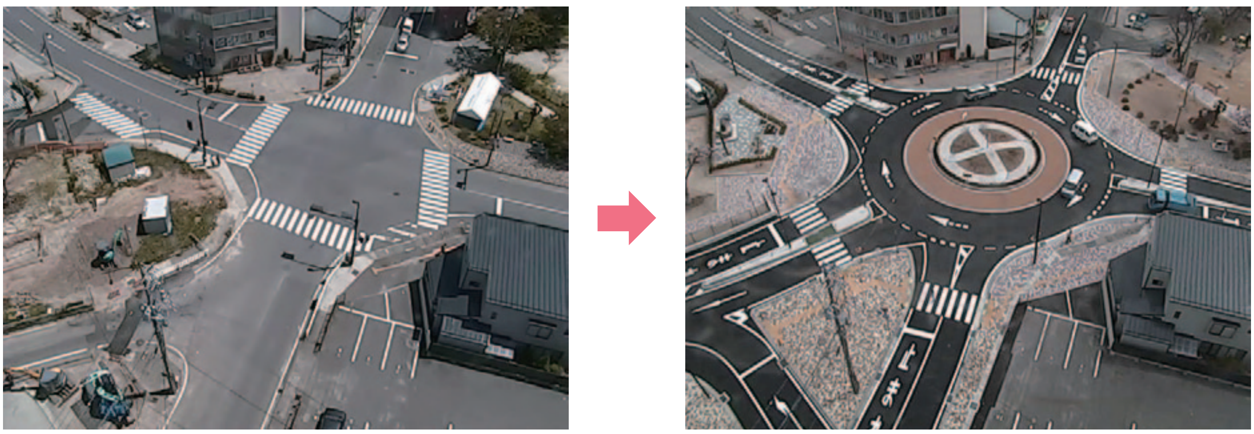
Figure 1. The roundabout on which field operational tests were performed in 2010; Azuma-cho, Iida City, Nagano Prefecture

2-3. Field operational test of a pedestrian detection system implementing light-emitting road studs in Azuma-cho

Because the 2010 field operational test was evaluated highly, Iida City decided not to revert the roundabout to its previous layout for the next year, and the roundabout was left in generally the same condition as in the field operational test. In 2011, various improvements to the intersection were made, such as modifying the location of crosswalks and installing structures at corners where semi-permanent road cones had been previously installed during the field operational test. Immediate relocation of some crosswalks was difficult for a variety of reasons, and as a result in some locations the distance between the circulatory roadway and crosswalks increased. For these locations in particular there were concerns about pedestrian safety. Therefore, with the cooperation of Iida City and the ITS Laboratory at the National Institute for Land and Infrastructure Management, the H2303 project was conducted. In this project, a system of light-emitting road studs was installed at the crosswalks of roundabout entries/exits for pedestrian detection in Azuma-cho, and an experiment was performed to verify the system's safety and functionality. The results confirmed that there was improved pedestrian safety during road crossing, and the system received many positive evaluations from users.

2-4. Japan's first conversion of a signalized intersection to a modern roundabout in Towa-cho, Iida City

As a result of the various field operational tests regarding the proposals and verifications performed in "A study on the practical deployment and promotion of safe and ecological roundabouts (H188/H2292/H2303)," conducted between 2009 and 2011 in cooperation with related government agencies and local residents, in 2012 a signalized intersection in the Towa-cho district in Iida City was converted to a modern roundabout (Fig. 2). This was a groundbreaking initiative that marked the first time that traffic signals had been removed and an intersection converted into a roundabout in Japan, making it an extremely valuable case study. In the H2420 project "A study on social implementation and promotion of roundabouts," which started in 2012, a technical investigation of this conversion was performed, and data from before the conversion were collected. Furthermore, methods were investigated for converting intersections into roundabouts while still allowing traffic in operation, and experiences during the construction and operation were recorded. On March 24, 2013, a modern roundabout that incorporated the latest technologies investigated and proposed by this project was finally opened in Towa-cho. The



(a) Before construction (2012) (b) Completion (March 2013)

Figure 2. Conversion of a signalized intersection to a modern roundabout; Towa-cho, Iida City, Nagano Prefecture
(Photo by Iida Cable Television)

roundabout featured a central island with a stepped apron construction, splitter islands at entries/exits, and a two-stage crosswalk, all Japan firsts.

2-5. Pre- and post-conversion comparison of the roundabout in Towa-cho

In the H2534 project, user behavior was compared before and after the conversion of the Towa-cho intersection to a modern roundabout. The results confirmed significant reductions in average vehicle delays and average pedestrian travel times following the conversion to a roundabout. When the intersection was signalized, intersection entry speeds and vehicle pass-through speeds were high and varied greatly, but following the conversion to a roundabout, entry speeds were verified to be lower and more stable. A much lower level of danger was verified for collisions between vehicles, especially those turning against traffic.

2-6. Roundabout planning, technical proposals for field operational tests, and roundabout promotion

Since its start, this project has continued to work toward the planning and design of roundabout conversions throughout Japan, as well as toward proposals, support, and promotion for further field operational tests. In the process, the project has attempted to grasp both citizens' needs and practical business needs, and as a result was selected by the Ministry of Land, Infrastructure, Transport and Tourism to perform further operational tests in Karuizawa-cho in Nagano Prefecture, Yaizu City in Shizuoka Prefecture, and Moriyama City in Shiga Prefecture. Roundabout conversions were successfully implemented through these operational tests and large effects were verified. During the fiscal year ending in March 2015, additional roundabouts will be implemented at unsignalized intersections in the cities of Suzaka and Azumino in Nagano Prefecture. We have continued to conduct seminars throughout Japan to deepen understanding of roundabouts, and in particular drew many attendees and much attention to our "Roundabout Summit" at Iida City in January, 2014. At that summit, formation of a "Roundabout Promotion Council" was declared, comprising the heads of seven regional governments.

3. Conclusions

While at first it took a long time to obtain understanding of roundabouts in Japan, the present research and activities have helped widely position roundabouts as a vital part of safe city planning among government agencies, engineers, and area residents. This has led to serious consideration of the introduction of roundabouts throughout the country, and with the amendments to the Road Traffic Law in June 2013, there has been no small amount of attention brought to the national level. In the future it will be necessary to continue on with these efforts to promote the dissemination of appropriate technologies and to continue the collection and analysis of data related to the currently ongoing cases.

A study on the role and limitations of motorcycles as a means of urban transport in Southeast Asia

1. Background and goals

Motorcycle ownership and use has advanced rapidly in Southeast Asian regions in recent years, making motorcycles a major mode of urban transport. Because cities in developed countries have not previously experienced such a phenomenon, the positioning of motorcycles with regards to traffic planning, design of transportation facilities, and transport operation is unclear, and focus has instead been placed on the negative aspects of motorcycles, such as increases in traffic accidents. However, motorcycles are compact, highly maneuverable, and have a relatively low environmental impact; thus, they may be a potentially beneficial mode of urban transportation by clarifying their positioning.

Given this situation, this project investigated the actual conditions of motorcycle usage from a variety of viewpoints and elucidated the issue. Specifically, we investigated subjects such as trends in motorcycle dissemination, the effects of motorcycles on traffic flow, traffic operation at intersections according to the motorcycle ratio, usage of motorcycles as taxis and delivery vehicles, and efforts toward increasing motorcycle safety. Through on-site investigations, analysis of statistical data, and interviews with experts in Thailand, Cambodia, and Vietnam, we were able to obtain much new knowledge.

As a representative example, below we present our findings resulting from investigations on actual traffic operation at intersections according to motorcycle ratios. Based on our findings, we make a proposal for efficient traffic operation at intersections and analyze the effects of conversion from motorcycles to four-wheeled vehicles on transport volumes.

2. Research content

2-1. Investigation of traffic operation at intersections according to motorcycle ratio and a proposal for efficient operation

Intersections are operated in a variety of ways according to the ratio of motorcycles to overall traffic volume. We recorded videos to perform a traffic survey in Bangkok, Chiang Mai, and Phnom Penh, three cities with different motorcycle ratios and different methods for traffic operation at intersections. We performed a quantitative evaluation of each intersection's traffic capacity[1] and investigated the

Project Leader: Atsushi Fukuda
Professor, Department of Transportation Systems Engineering, College of Science and Technology, Nihon University

(1) Intersection traffic capacity: At a single-path portion of a road, capacity is taken to be the number of vehicles that can pass through that location in one hour. At intersections, however, traffic passes through from different directions, reducing the number of vehicles that can pass. It is therefore important to determine intersection capacities.

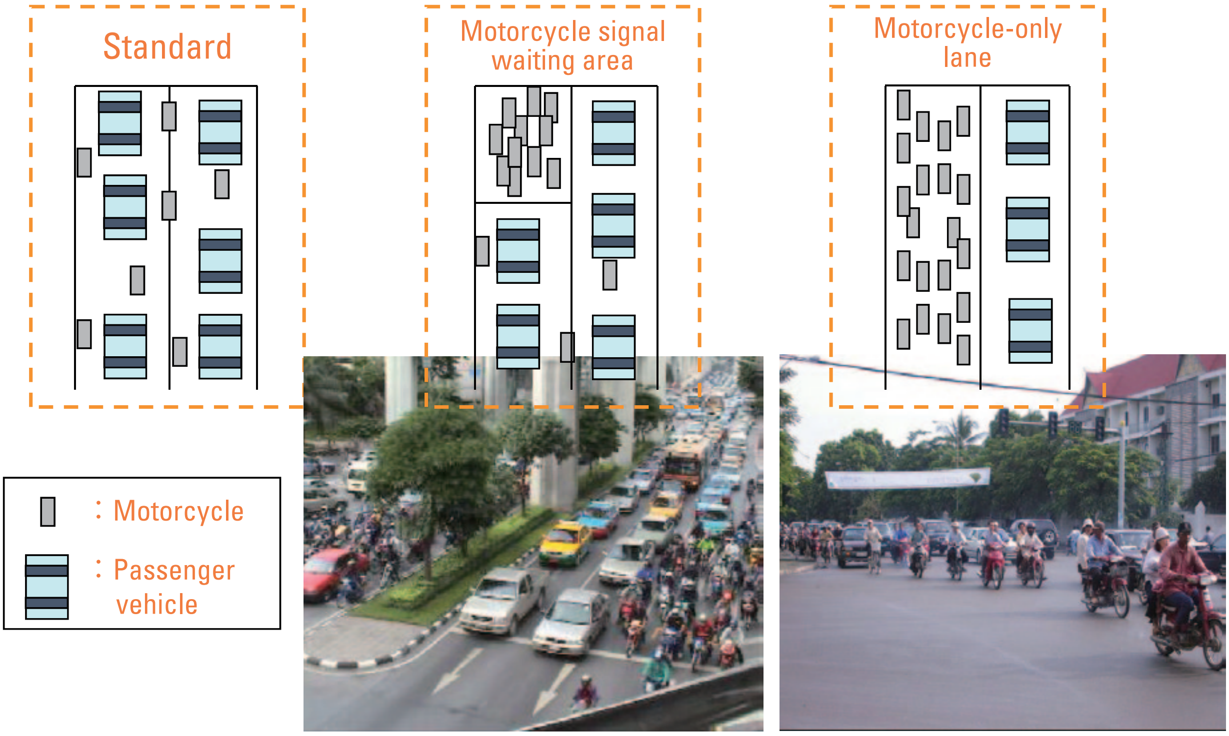
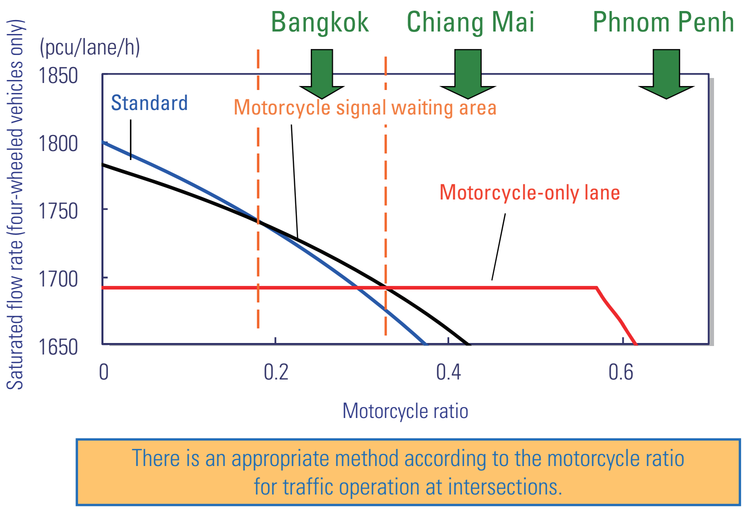


Figure 1. Three types of intersection configurations

intersection configurations that were most efficient for traffic flow control according to the variations in motorcycle ratio.

We found that an increased number of motorcycles traveling alongside four-wheeled vehicles at a standard intersection can impede traffic of four-wheeled vehicles. In contrast, we found that lane-splitting motorcycles did not have an effect on the operation of four-wheeled vehicles.

Therefore, comparing standard intersections with intersections that have a designated area for motorcycles to wait for traffic signal changes, the latter have the negative effect of pushing back the stop line for four-wheeled vehicles, delaying their start times. However, there was a positive effect in that allowing motorcycles to collect at the front of signal wait areas reduced the number of motorcycles running between cars. We thus found that in situations where there is a low motorcycle ratio,



Saturated flow rate on the vertical axis refers to the maximum number of automobiles that can flow into an intersection without travel interruption during a green light. This is used as the base value for finding intersection capacity.

Figure 2. Changes in intersection capacity due to motorcycle ratio

standard intersections may allow for more efficient traffic flow, but the opposite may be the case with higher ratios. We observed an effect due to establishing motorcycle-priority lanes and to the narrowed lanes for four-wheeled vehicles. This indicates that the optimal intersection configuration may differ according to motorcycle ratios.

2-2. Impact on transport volumes due to conversion from motorcycles to four-wheeled vehicles

There is an assumption that increased economic development will promote four-wheeled vehicle usage, thus lowering motorcycle usage ratios in cities where these ratios are currently high. We therefore analyzed the potential effects of this conversion from the viewpoint of transport volume.

In Bangkok, each motorcycle carries on average 1.2 people, while each automobile carries on average about 1.5. Under the assumption that changes in the motorcycle ratio will not have a large impact on the average number of riders per motorcycle or four-wheeled vehicle, we calculated changes in cross-sectional throughput (the number of persons passing through an intersection lane per hour) for various motorcycle ratios. Note that when performing these calculations we assumed optimal intersection configuration for the motorcycle ratio.

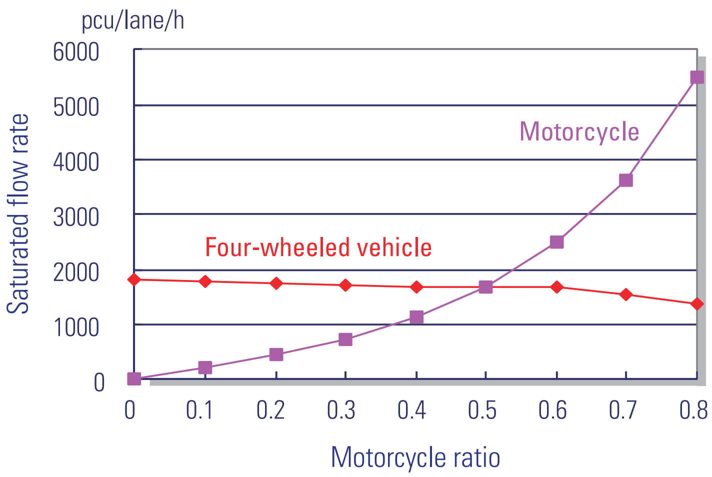


Figure 3. Changes in intersection capacity due to motorcycle ratio

We could ascertain that decreased motorcycle ratios resulted in a decreased number of persons passing through intersections, and that such reductions were larger with higher motorcycle ratios. The current motorcycle ratio in Phnom Penh is approximately 0.7 and that in Bangkok is approximately 0.3. This indicates that Phnom Penh in particular will experience serious traffic congestion should four-wheeled vehicles become more popular. However, this also means that appropriate traffic operation for the utilization of motorcycles may increase transport capacity.

3. Conclusions

The various analyses performed in this project indicate that motorcycles are a highly space-efficient means of transportation. We believe that the development of motorcycle-based taxis and messenger services in Southeast Asia is a result of motorcycles' mobility making them well suited as a supplemental means of small-scale goods distribution and trunk route transport.

Increased demands for transportation result in increased traffic volume. However, trying to accommodate for this volume by focusing on only four-wheeled vehicles will increase private marginal costs(2) and road usage costs. This translates into decreased total social benefit. In contrast, utilization of space-efficient motorcycles can decrease private marginal costs, thereby increasing benefit and allowing more comfortable road usage.

Motorcycle ownership is currently declining in Japan, but intelligent utilization of motorcycles in Southeast Asian cities may help prevent the worsening of road conditions that accompanies development of automotive societies. However, attaining this utilization will necessitate the solving of many problems. The over-capacity motorcycle-riding that is frequently seen in Southeast Asia is dangerous, and there is a need for education to improve driving etiquette. As indicated above, there is also a need for appropriate road maintenance and traffic control better suited to motorcycle operation. Thus, implementing these changes will require not only traffic engineering and traffic planning, but also urban planning efforts.

4. Future outlook

In Japan, there are numerous studies regarding the utilization of ultra-compact vehicles that are larger than motorcycles but smaller than small automobiles. How best to position the role of such personal vehicles—including motorcycles—as a part of urban transport, and how to connect them with public transportation, are important issues not only for Southeast Asian cities but also for cities throughout the world. In the future, it will be necessary to explore the roles and limitations of such vehicles from a variety of viewpoints regarding environmental and spatial efficiency and traffic safety issues, leading toward the development of an ideal traffic system.

(2) Private marginal cost: An increased number of automobiles results in congestion and lower traveling speeds. Private marginal cost is a generalized cost referring to the amount of worsened congestion resulting from the increase of a single car (Social marginal cost: Under these conditions of increased number of automobiles, worsened congestion results in increased costs due to congestion not only to the added car, but to other cars as well. Social marginal cost refers to this amount of increase).

Practical application of a public involvement-type system for planning and evaluating road traffic safety measures

1. Background and goals

In 1997, the year this project started, about 10,000 people each year died in road traffic accidents in Japan. After the beginning of the twenty-first century, this number significantly decreased, but there are still an excessive number of road traffic accident-related fatalities. Even though fatality rates have been cut in half, the present need for further reduction remains unchanged.

Developing increasingly sophisticated road traffic safety measures for further reduction of traffic accidents will require not only governmental policies, but public involvement as well. This project aims at constructing public involvement-based road traffic safety policies and evaluation systems, using these as tools to conduct pilot surveys, and verifying their effects.

2. Research content

This project consists of four pillars, based on which local governments can reduce road traffic accidents by half over the medium term:

1. Objective data assessment of road traffic accidents and "*hiyarihatto* experiences"(1)
2. Information exchange among citizens, and between citizens and local governments
3. Training and utilization of experts
4. Quantitative evaluation of the effects of road traffic safety measures

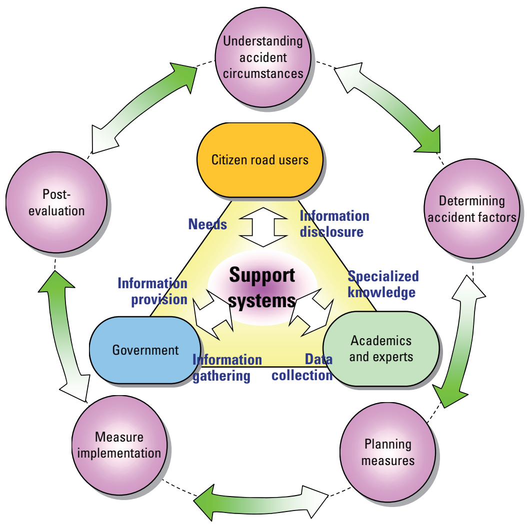


Figure 1. Road traffic accident reduction system for local governments

To put this into practice, we developed a road traffic accident reduction system for local governments that utilizes Web-based GIS and the Internet, and applied this system to the city of Kamagaya, Chiba Prefecture, as a case model. The system is composed of four subsystems, allowing for implemen-

Project Leader: Hirokazu Akahane
Professor, Department of Architecture and Civil Engineering, Faculty of Engineering, Chiba Institute of Technology

(1) "*Hiyarihatto* experiences": Named after a Japanese term referring to a close call, *hiyarihatto* experiences are subjective reports by road users who experience feelings of fright and danger on roads.

tation of road traffic safety measures according to the PDCA cycle.(2)

(1) Road traffic safety measure support subsystem

Utilizing a road traffic accident database as its core, this system allows for advanced GIS(3)-based aggregation, searching, and spatial analysis of accident data. Using the *hiyarihatto* map creation system, which will be described in the following section, the road traffic safety measure support system is capable of integrating accident data with *hiyarihatto* experience reports from road users and district residents.

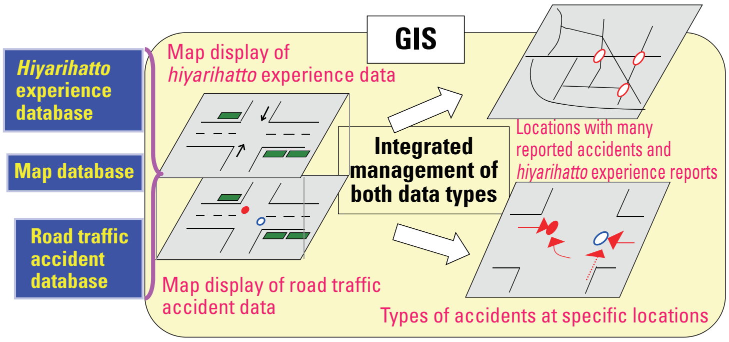


Figure 2. GIS integration of data regarding accidents and *hiyarihatto* experiences

The system thus allows extraction of locations with road traffic safety problems, making it possible to organize information in various ways, such as by type of accident and by conditions under which accidents occur.

(2) Road traffic safety information web-based subsystem

This subsystem is composed of a *hiyarihatto* map creation system and a road traffic safety information website. The *hiyarihatto* map creation system allows road users and area residents to participate via reporting their *hiyarihatto* experiences using a website managed by local governments, which uses this information to generate a *hiyarihatto* map. The road traffic safety information website has information related to traffic safety policies managed by local governments, and such collection of information from road users and area residents along with information presentation and dissemination by

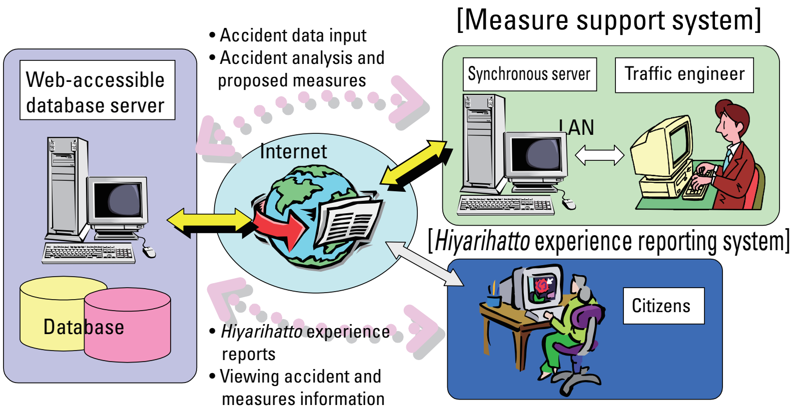


Figure 3. Road traffic safety information web-based subsystem

(2) PDCA cycle: A method of continual operational process management performed by repeatedly Planning, Doing, Checking, and Acting.

(3) GIS: Geographic information system. This refers to technologies for comprehensively managing and processing data with associated positioning information (spatial data) and presenting that data visually, allowing for advanced analysis and rapid decision making (Source: http://www.gsi.go.jp/GIS/whatisgis.html).

local governments enables the sharing of traffic safety information between local governments and citizens.

(3) Road traffic safety measures examination subsystem

This subsystem uses investigation and analysis of locations extracted from the road traffic safety measures support subsystem as candidates for installing measures, allowing for scientific identification of accident factors and subsequent prioritization of safety measures. This mechanism employs not only traditional forms of public involvement, such as questionnaires and briefings, but also workshops and pilot surveys that allow citizens to be directly involved in the examination and implementation of measures.

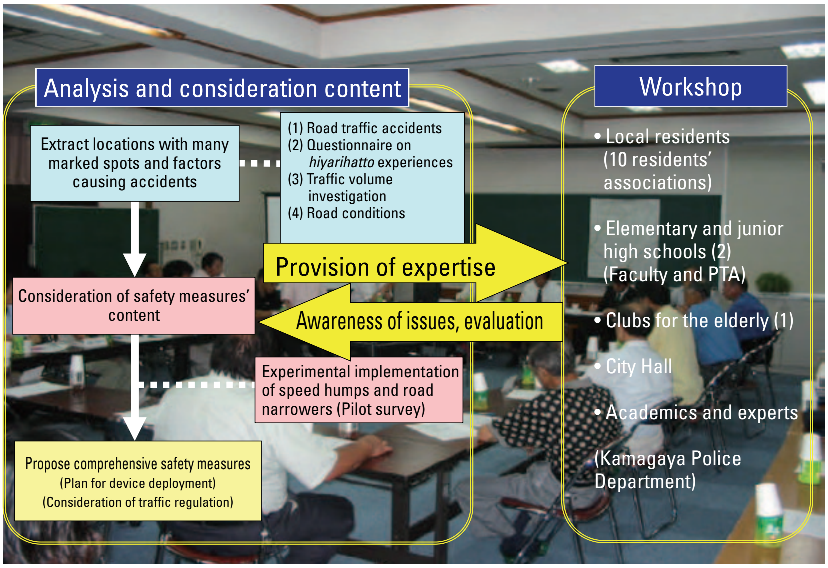


Figure 4. Framework of road traffic safety system measures in the Higashi-hatsutomi district

(4) Road traffic safety measures implementation evaluation subsystem

This subsystem evaluates the effects of implemented traffic safety measures and provides feedback, allowing further improvements to be made based on the subsystem's evaluations. Two forms of evaluation can be performed: objective evaluations based on quantitative comparison of the situation before and after measure implementation, according to the aforementioned road traffic safety measure support and road traffic safety information web-based subsystem, and subjective evaluations based on collecting and sorting road user and area resident opinions regarding road

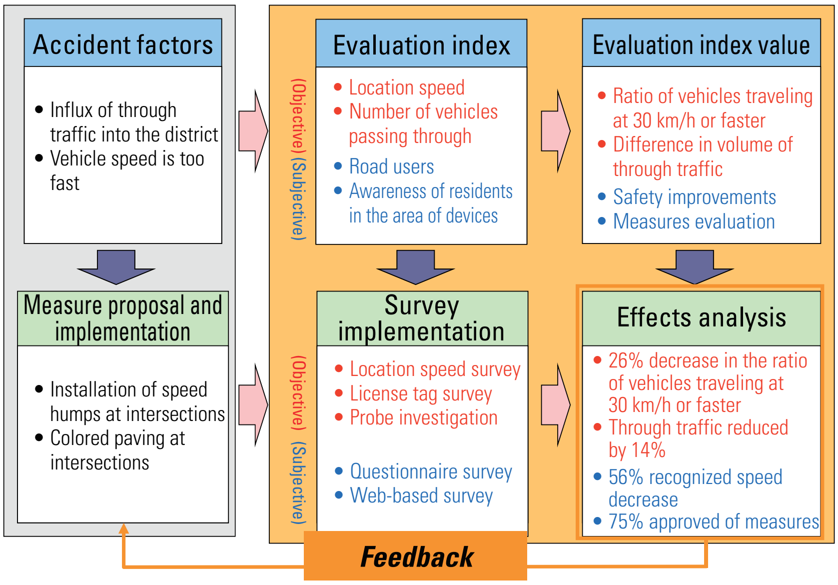


Figure 5. Measure effect evaluation subsystem (speed reduction measures)

traffic safety measures, according to the road traffic safety information website.

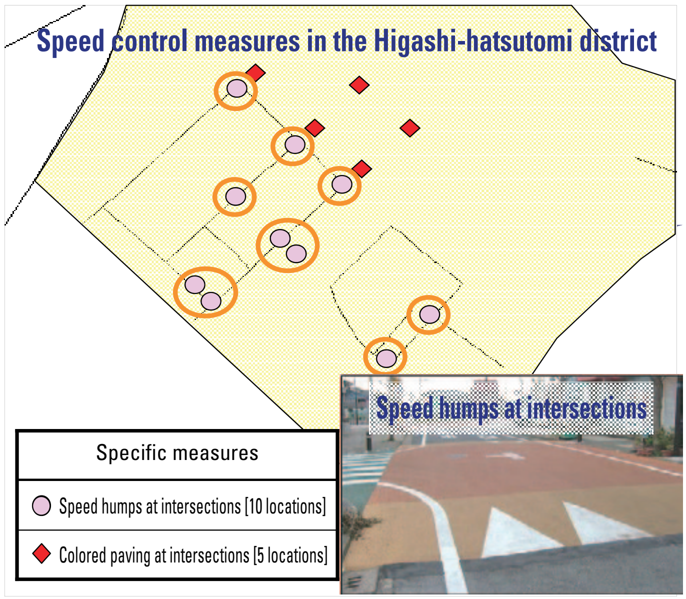


Figure 6. Installing speed humps, etc. at intersections (Higashi-hatsutomi district)

From 2001 to 2002 in Kamagaya, we initiated a pilot survey and evaluated the effects regarding measures for intersections with high accident rates, and verified an approximate 60% reduction in traffic accidents. Encouraged by these results, in 2004 we performed a pilot survey on comprehensive safety measures regarding through-traffic on residential roads in Kamagaya's Higashi-hatsutomi 4-chome district, which covers an area of approximately 64 ha containing 1,800 households. Based on information sharing and consensus building at a workshop hosted by local government representatives, the local city hall, and experts, the district implemented measures such as installing speed humps at ten intersections, resulting in an approximately 56% accident reduction. Furthermore, the number of reported sudden *hiyarihatto* experiences and locations fell by 77% and 65%, respectively. Based on these experiences and results in Kamagaya, we created and verified our workflow and developed a training program for users.

3. Conclusions

We have transferred the system from Kamagaya to the neighboring cities of Ichikawa and Shirai, which have approximately four times and one half the population of Kamagaya, respectively, with the goal of clarifying challenges to system construction and operation. This has helped verify the versatility and effectiveness of the "Kamagaya Scheme." We have also realized multilingualization of the system through the use of Internet-based translation services such as application service providers, and have begun operation of the system in Penang, Malaysia.

4. Future outlook

Dissemination and continuation of the "Kamagaya Scheme" will require (1) the hosting of seminars for agencies responsible for traffic safety policy implementation, (2) implementing workshops related to safety technologies and administrative practices for road traffic safety engineers, (3) supporting implementation and operation of the scheme, and (4) supplementing the various databases used in the scheme and promoting sharing between local governments. We believe that doing this will make our system an increasingly useful tool for countries to collaboratively share experiences and accumulate data relating to road traffic safety measures.

Identification of brain regions associated with the central and peripheral visual field and applications for improving traffic safety

1. Background and goals

The perception and cognition of pedestrians appearing in the peripheral vision of drivers, and vice versa, is essential to traffic safety. Therefore, studies of cognitive processing in central and peripheral vision are urgently needed to reduce traffic accidents.

The aim of this study was to make recommendations for the realization of traffic safety by revealing the visual attributes that play important roles in human cognition and behavior.

1-1. Main study point

Three factors were the focus of this study: elderly individuals, intersections, and night-time.

Elderly individuals: the proportion of elderly individuals in fatal traffic accidents continues to increase.

Intersections: according to the study of traffic fatalities by road type, approximately half the fatalities happen at the time of crossing streets or intersections.

Night-time: the number of traffic fatalities peaks from dusk on into night-time.

The probability of traffic accidents will increase further when these factors are concurrently present.

To investigate the correlation between the three factors and human visual function, special attention was paid to peripheral vision, because proper perception and cognition of pedestrians (automobiles) in the peripheral vision by drivers, and vice versa, will definitely improve traffic safety.

The functional properties of peripheral vision in humans have been investigated from the perspective of cognitive psychology but have yet to be fully elucidated. In addition, little information is available on the central processing of visual information originating in the peripheral visual fields. In this study, we therefore performed cognitive psychological experiments to investigate dynamic vision and the effects of aging as well as neurological experiments to quantitate the cortical representation of peripheral vision using functional magnetic resonance imaging (fMRI). The properties of a wide field of view and traffic safety were also investigated.

Project Leader: Jinglong Wu
Professor, Graduate School of Natural Science and Technology, Okayama University

2. Research content

2-1. fMRI study on the physiological characteristics of a wide field of view

After developing a wide-field stimulus presentation device that operates under the MRI (high magnetic field) environment, fMRI was performed to reveal functional differences between central and peripheral vision.

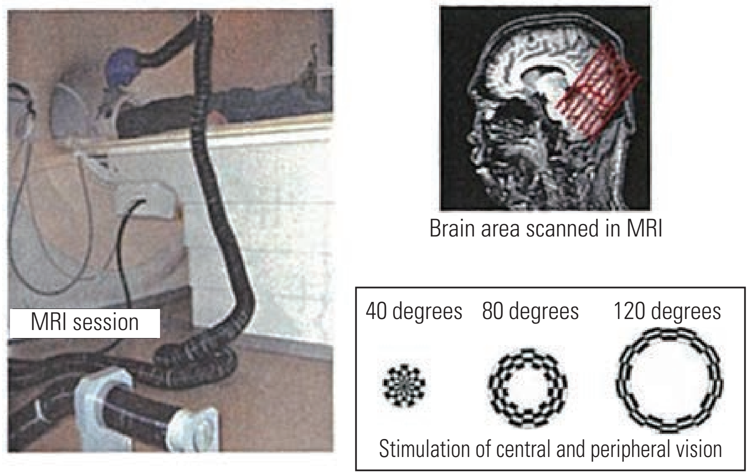


Figure 1. Imaging device and technique for cortical representation of the visual field

First, retinotopic mapping (functional mapping of the visual cortex)[(1)] and quantitative analysis of central and peripheral vision were performed. Conventionally, it has been possible to examine only up to 60 degrees of visual angle due to the limitations of temporal resolution in fMRI. Therefore, to perform this experiment, we developed a new stimulus presentation device that enables the mapping of up to 120 degrees of visual field. As a result, we could confirm that a diffuse area adjacent to the occipital lobe was the brain region involved in the processing of peripheral vision. Use of the device, with its wider field of visual stimulation, further revealed that this diffuse area was more extensive than previously studies have reported.

Quantitative analysis showed that the size of the brain area involved in information processing decreases as the visual field nears the far periphery. Furthermore, the study of the temporal frequency response properties of central and peripheral vision showed that the maximum response was elicited by a temporal stimulation frequency of 4 Hz when the eccentricity was 20 degrees (central visual field) (1) and by temporal frequencies of 4–8 Hz when the eccentricity was 40 degrees (2), but only small differences were observed in the responses to individual frequencies when the eccentricity was 60 degrees (peripheral visual field) (3).

2-2. Cognitive psychological study on the characteristics of wide field of view

A conventional manual device to measure dynamic visual field was automated to quantitatively analyze the dependency of dynamic visual field on brightness and color. Differences in dynamic visual field between young and elderly individuals were also measured and analyzed. Further, we modified the light

---

(1) Retinotopy: Using a similar principle as in cameras, light information from an object is projected onto the retina, where it is converted into electrical signals by photoreceptors. In this process, spatial information in the retina is maintained in the visual cortex in the brain. For example, information from the center of the retina is sent to the posterior of the visual cortex, while more anterior regions of the visual cortex process information originating from more peripheral locations of the retina. Such reconstruction of spatial information in the retina by the visual cortex is called retinotopy.

source in the measurement device, which allowed us to quantitate the dependency of dynamic visual field on brightness and color, and to investigate how aging affects the dependency.

Dynamic visual field is defined as a visual range within which humans are able to discriminate a moving object. Dynamic visual field is particularly important when driving or crossing streets. In this study, the Goldmann perimeter was remodeled to be functionally flexible and more accurate. Underestimation of dynamic visual field by subjects is a serious problem, especially when studies involve fast-moving visual targets or elderly individuals with slow reaction speeds. In this study, we therefore measured the response time of subjects under different condition to correct for this underestimation.

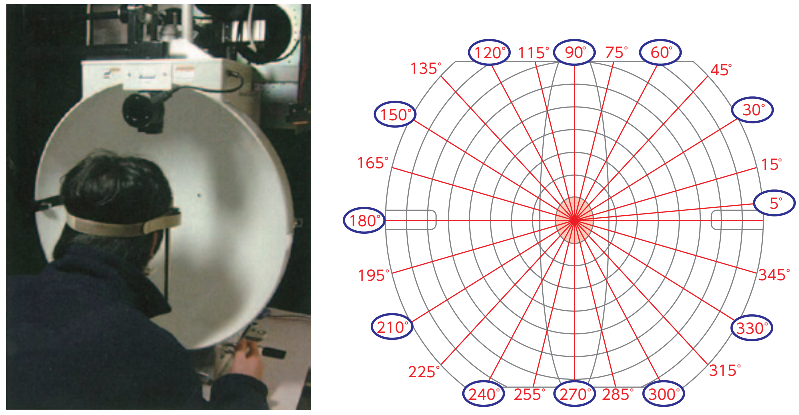


Figure 2. Development and use of a dynamic visual field measurement device

Subjects were 5 individuals aged 20–23 years, 9 individuals aged 50–64 years, 4 elderly individuals aged 65–74 years, and 4 elderly individuals aged 75–80 years. Subjects were instructed to stare at the center of the screen and push a button as soon as they notice a target moving inward from the periphery at a given constant speed. Results indicated that dynamic visual field was relatively wider in younger individuals than in elderly individuals. With regard to speed dependency, all age groups had a tendency to decrease slightly as the speed of the target increased. The visual field in elderly individuals aged 75–80 years was approximately half the visual field in individuals in their 20s, revealing a marked effect of aging. However, dynamic visual field was not lost evenly in an age-dependent manner, and dynamic visual field instead varied greatly among individuals.

2-3. Investigation of the association between wide field of view and traffic safety

We plan to apply the findings of this study to improve traffic safety and recommend the revision of road sign installation criteria and of regulation for traffic safety education aimed at elderly people.

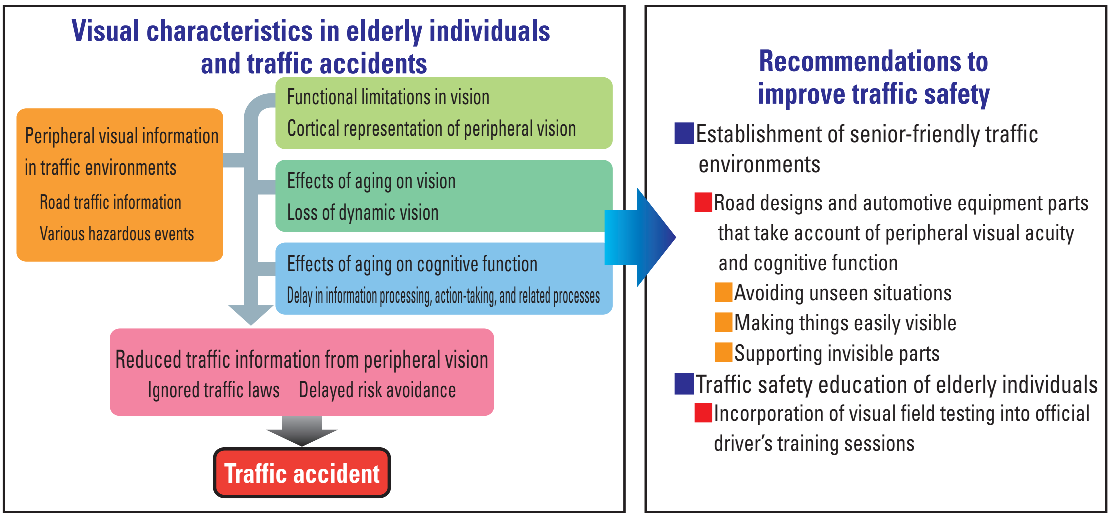


Figure 3. Recommendations to improve traffic safety based on the relation between visual characteristics in elderly individuals and traffic accidents

3. Conclusions

Through the investigation of central and peripheral vision in humans, we were able to reveal under what circumstances peripheral visual acuity was compromised. The effect of aging on dynamic visual field was substantial, particularly among elderly individuals aged 75–80 years because of severely impaired cognition of moving objects in peripheral vision.

In retinotopic mapping, the central information processing area for peripheral vision was narrow compared with central vision. Furthermore, the study of brain activity in response to temporal frequencies showed that the maximum response was elicited by a temporal stimulation frequency of 4 Hz when the eccentricity was 20 degrees (central visual field) (1) and by temporal frequencies of 4–8 Hz when the eccentricity was 40 degrees (2), but only small differences were observed in the responses to individual frequencies when the eccentricity was 60 degrees (peripheral visual field) (3).

4. Future outlook

When moving on a street (including driving), we sense and process environmental signals before taking proper actions. To act safely, it is necessary to accurately execute the 3 stages of information processing—perception, cognition, and action—and as the organ that governs these functions, the brain should be investigated to reduce traffic accidents. In this study, to recommend traffic safety measures, special attention was paid to intersections and to elderly individuals, who are highly associated with traffic accidents, to investigate the brain function involved in wide-field visual acuity and the effects of aging on dynamic vision. It is important to continue basic research with emphasis on the central mechanisms involved in perception, cognition, and action in order to reduce the number of traffic accidents in the future.

An educational program for better control of emotions while driving

1. Background and goals

Negative emotions such as irritation, impatience, and anger have been frequently indicated as causal factors in accidents in various studies on human factors. However, this issue tends to be treated as an inattention error by the driver or as a legal violation, and is rarely directly taken up as an educational theme. In this study, we address this issue as a topic for driver education. The goal of the project was to develop an educational program for better control of emotions and examine the effectiveness of the program (Fig. 1).

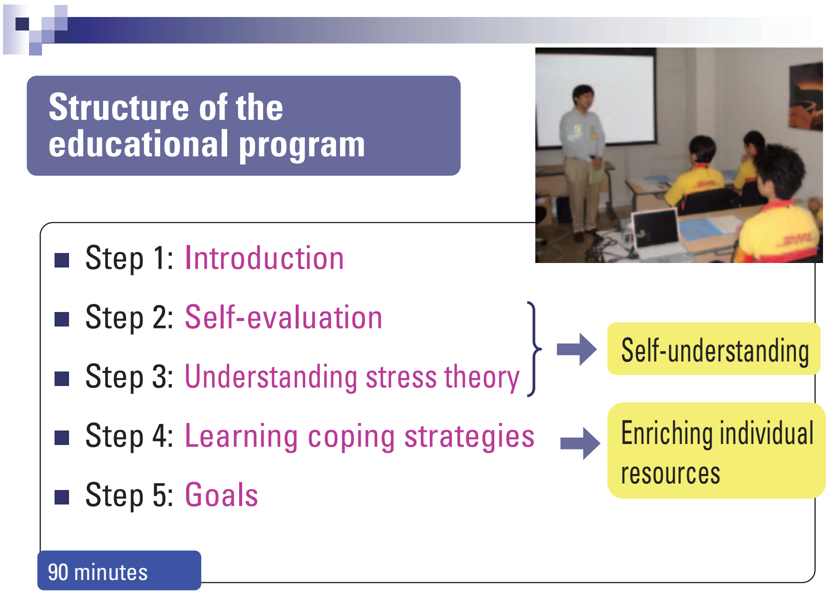


Figure 1. Overview of the educational program

Emotional control is one of the most important skills required for safe driving and plays a dominant role in other safe driving skills such as vehicle maneuvering and hazard perception according to a hierarchical model of driver behavior. However, it is difficult for a third party to determine what should be learned in an educational program because emotional control skills are highly dependent on individual characteristics. The most important pedagogical point is to help learners understand their own emotional tendencies and to proactively develop emotional control strategies best suited to the individual. This project aimed at providing opportunities for such learning, by developing an educational program for improving emotional control skills.

Project Leader: Kazuhisa Ogawa
Professor, Teacher Training Center, Tohoku Institute of Technology

2. Research content

2-1. Methods

The research project consisted of two surveys. The participants in the surveys were 102 professional drivers (average age 37.38 years) employed by transport and delivery service companies. The first survey was conducted before and after implementation of the educational program to analyze changes in driving behavior using driving recorders attached to vehicles that the participants operated during daily work. We also measured changes in participants' awareness (stress reaction and feelings of self-efficacy) before and after the program. We also conducted simple interviews one month after the program to investigate awareness changes following program participation. The second survey investigated only changes in awareness before and after participation in the educational program.

We used three questionnaires. Questionnaire I presented examples of emotional states during driving, and the degree to which the participant thought the emotion applied was taken as a measure of stress reaction (Fig. 2). We also asked participants to rate whether they have been able to easily cope with their emotional state, and used this as a measure of self-efficacy.

			Response A: How well do the following statements describe your feelings under the given circumstances?					Response B: How easy or difficult is it for you to cope with these circumstances well?			
			Very well	Somewhat well	Not very well	Not well at all		Difficult	Somewhat difficult	Somewhat easy	Easy
1		Drivers who don't thank me when I yield to them are rude.	4	3	2	1	➡	4	3	2	1
2		I suddenly become irritable when I get caught in traffic when I'm busy.	4	3	2	1	➡	4	3	2	1
3		When I'm trying to make a turn against oncoming traffic but can't find an opening, I get very anxious due to the line of cars piling up behind me.	4	3	2	1	➡	4	3	2	1

Figure 2. Part of questionnaire I

Questionnaire II was for evaluating the educational program. This questionnaire was used to identify which parts of the program participants found useful and to get information about their overall impressions regarding the program. We used the results of this questionnaire to evaluate acceptance of the educational program.

Questionnaire III was produced based on the Big Five theory(1) and was used to assess the personality traits of the participants.

(1) A recent theory for explaining personality. This theory categorizes the various personality traits into five dimensions: extroversion, neuroticism, openness to experience, conscientiousness, and agreeableness.

2-2. Results

(1) Changes in stress reaction and self-efficacy

We calculated a scaling score for eight items of questionnaire I regarding anger toward others' behavior. We converted this to average per-item scores and analyzed changes after participation in the educational program. Higher scores indicate a stronger stress reaction and stronger feelings of self-efficacy. As shown in Figure 3, stress reaction was reduced after program participation and feelings of self-efficacy were improved.

Figure 3. Changes in stress reaction and self-efficacy following education

A similar analysis was performed on five items related to feeling rushed under the pressure of time, and rating scores were compared before and after program participation. For impatience, we also found effects of reduced stress reaction and increased feelings of self-efficacy after the program.

Analyzing the relation between age and changes in awareness indicated that age in particular was a factor that influenced feelings of impatience after the program. Both young participants (aged 30 years or younger) and middle-aged participants (aged 31 years or older) indicated reduced stress reaction and improved feelings of self-efficacy after the program, but the change was greater for the young participants.

Analysis of the relationship between changes in awareness and personality traits of the participants indicated no association with stress reaction. Regarding feelings of self-efficacy, however, a significant interaction was found between feelings of anger and extroversion. We divided participants into two groups of higher and lower extroversion scores. We found that changes in feelings of self-efficacy were larger among the participants with higher extroversion scores. In other words, it was suggested that participants who tend to direct mental energy outward found it easier to cope with their anger toward other road users after the program.

(2) Participants' evaluation of the educational program

Questionnaire II contained 17 question items posed as a 4-point Likert scale. Participants evaluated the program favorably: Over 80% of participants gave positive responses ("4: Agree" or "3: Somewhat agree") for all question items.

(3) Changes in driving behavior

No statistically significant changes were found regarding driving behavior of the participants following the program.

3. Conclusions

Participation in the educational program resulted in reduced stress reaction regarding feelings of anger and impatience. Such changes in awareness were particularly noticeable among young drivers. Also, highly extroverted drivers showed particular improvement in feelings of self-efficacy to control anger. Evaluation of the education program indicated high acceptance overall. However, no definite changes in driving behavior were observed.

In the future, it will be necessary to develop more sensitive measurement indicators for changes in driving behavior. A possible measurement method is to observe specific behaviors such as visual checking and stopping at an intersection when a stressful event occurs on the road. Another problem to be solved is the development of follow-up training to sustain the improvement in emotional control skills. It is possible that the educational effects found in this study are only temporary changes. Finally, dissemination of this emotional control educational program requires development of a manual. We hope to develop specific educational measures for organizing and resolving the many psychological problems that drivers face.

4. Future outlook

In addition to continued verification of the educational effects, instructor training is a major issue related to dissemination of this educational program. Traditional educational styles in which instructors attempt to instill knowledge in learners are not suited to deriving self-understanding. In the future, it will be necessary to plan instructor training workshops that provide learner-oriented instructional methods such as coaching techniques.

A study on safety measures considering the psychological behavior characteristics of cyclists, from adolescents to the elderly

1. Background and goals

Compared with Western countries, Japan has a higher rate of bicycle accidents. In 2009, bicycle accidents caused 14.1% of traffic fatalities and 17.1% of traffic injuries. Preventing bicycle and pedestrian accidents has become an essential issue to address for further reducing the rate of traffic accidents in the future. Regarding bicycle accidents, young people, junior high school students in particular, accounted for nearly 70% of injuries, while the elderly accounted for 60% of fatalities. There is thus a need for determining the causes of these accidents and planning measures to prevent them.

This project therefore explores the possibilities for effective educational programs and awareness activities targeting cyclists, and gives recommendations for improving bicycle safety, including those related to road environments and social systems.

2. Research content

2-1. Conducting an educational program for junior high school students

In FY 2010 and 2011, we conducted an educational program at two junior high schools in Suzuka City, Mie Prefecture. Students participated in voluntary group work to create *hiyarihatto* maps,[1] investigate problems, and make specific proposals for improvement plans (Fig. 1).

Figure 1. Example of created traffic *hiyarihatto* map

As a result of these efforts, we found that students 1) plan routes to avoid major roads and large intersections that invoke psychological feelings of danger, 2) do not have sufficient space to walk or cycle due to narrowness of

Project Leader: Kazumi Renge
Professor, Department of Psychology, Faculty of Psychology, Tezukayama University

(1) A *hiyarihatto* map, named after a Japanese term for a close call, is a map that indicates areas in which participants feel a sense of danger.

streets, 3) hold the misunderstanding that the same traffic rules apply to pedestrians and cyclists, and 4) engage in what subjectively seems to be danger avoidance behavior, but instead puts them in more dangerous circumstances.

There were many cases where students shared problem awareness through actively developing discussions, resulting in specific opinions about what students themselves can do in regard to not only improving the traffic environment but also performing safety confirmation behaviors that do not rely on their senses, ensuring proper understanding of bicycle traffic rules, and finding safer routes for commuting to school.

2-2. Survey of bicycle behavior among the elderly and development of education programs

Previous research has shown that elderly adults who do not have a driver's license are far more likely to be involved in accidents than those who do. We conducted a study to elucidate differences in behavior characteristics between elderly adults with a driver's license and those without. We performed an investigation of cycling behavior at the Nara driving school in Nara Prefecture on October 4, 2010 and October 17, 2011. The participants were aged 62 to 94 years, comprising 21 individuals who had a driver's license and 27 who did not.

Gyro sensors were used to count the number of times participants looked left and right, and to measure viewing angles and viewing times. An external camera was also used to count the number of times participants looked left and right. A small helmet-mounted camera was used to monitor running positions (Fig. 2). Participants walked and cycled through an intersection with poor visibility and through an experimental course with parked cars.

Figure 2. Gyro sensors mounted on the head and knee

A general tendency was found in all participants for a lower frequency of safety checks when riding bicycles compared with walking, as was a tendency for riding in the middle of the road. These tendencies were particularly pronounced in participants who did not have a driver's license. We therefore consider it necessary to focus on non-license holders when conducting instruction and training of elderly cyclists.

2-3. Image-based experiment on cycling environment

Bicycles are legally considered to be vehicles and therefore as a rule must travel on streets not sidewalks. However, there has been insufficient investigation of under what conditions cyclists actually adhere to this principle. It would be preferable to establish bicycle lanes, but there are many cases where the road width is insufficient to make that practical. One possible solution is road indicators with bicycle

You are currently traveling along a road

Road conditions

Lane width	Number of lanes	Automobile traffic
3.5–4.75 m (mid.)	2	1–3 cars/min (mid.)

Sidewalk conditions

Sidewalk width	Pedestrian traffic	Signage indicating bicycle traffic allowed on sidewalk
4 m or more (wide)	6 people/h (low)	None

Figure 3. Example image of a virtual road space from a bicycle viewpoint

marks[(2)] to promote road usage by cyclists.

We therefore performed an image-based experiment to grasp the effect of spatial development on the use of bicycle lanes and road markings from the perspective of both cyclists and automobile drivers (Fig. 3, 4). To better grasp general trends in bicycling behavior, we performed a preliminary investigation targeting 32 university students in January 2012, and then in March 2012 conducted an Internet-based survey involving 216 participants (aged 20–74 years, 107 men, 109 women).

For the experiment we created static images of a virtual road space under different conditions, showed participants each image, and asked questions. In the case of bicycle viewpoints, we asked participants to tell us where they would ride and their reasons for doing so. In the case of automobile viewpoints, we presented a bicycle traveling in front of the automobile, and asked participants where they would pass by it and at what speed.

Also, knowledge likely has an effect on the decision to ride bicycles on the street or the sidewalk, so we divided participants into four groups and provided each with varying levels of information regarding traffic rules, traffic signs, and road indicators, thereby creating differences in knowledge. We also divided participants according to sex and driver's license status and investigated the relevance of these factors.

In the image-based experiments from the bicycle viewpoint, 66% of participants said they would travel on the road if a bicycle lane was present, indicating the effectiveness of bicycle lanes in promoting road usage. In contrast, the presence of on-road bicycle markings had nearly no effect on preference for road usage.

There was an association between participant knowledge and road use selection, with groups presented with less information indicating a lower preference for roads. Regarding sex and the presence or absence of a driver's license, male license holders and female non-license holders indicated an increased preference for roads.

In the image-based experiments from automobile viewpoints, the presence of signage for bicycle lanes had no effect on crossing behavior at large intersections, but bicycle lanes resulted in a trend for increased distance

Situation #11

Figure 4. Example image of a virtual road space from an automobile viewpoint

(2) Bicycle marks: Road surface markings placed at regular intervals to indicate where cyclists should ride.

from the road edge. While the presence of bicycle lanes worsened crossing behavior at smaller intersections by increasing distance from the road edge, the presence of bicycle signage indicated the same trend as in the case of no signage for riding closer to the road edge.

3. Conclusions

Based on the above results, we provide recommendations as follows.

For young people, there is a need for education and activities that emphasize motivation. We also consider skill evaluation contests and the use of automotive simulators along with voluntary group work activities to be important. For the elderly, it is necessary to develop living environments and to devote substantial efforts toward elderly non-license holders. Finally, it is necessary to improve the cycling environment through the development and operation of bicycle lanes.

It is important that these measures be considered as guidelines for improving cycling safety. While this project has attempted to take on such issues in a practical manner, there is a need for continued separate studies toward their implementation.

4. Future outlook

The Road Traffic Act of 2013 calls for stricter enforcement of bicycles traveling on roads near the edge. To promote both the development of road traffic environments, improved knowledge of the law and safety among cyclists, and improved driving skills, school-based education and community safety training programs should be implemented nationwide. Such development of cyclist training measures and improvement of the road traffic environment can likely be further implemented toward safety measures for automobile and scooter operators in developing countries.

Addressing issues associated with prehospital emergency transportation

1. Background and goals

We all take advantage of the 119 emergency ambulance services in the event of unexpected injury or acute illness. In Tokyo, it takes as much as 6 min 38 sec on average (as of 2012) for an ambulance to arrive on scene after mobilization. Moreover, on-scene time continues to increase every year, potentially delaying treatment of high acuity illness, such as cardiovascular diseases and stroke, and causing permanent damage or serious complications. These issues may turn rescue activities that would have saved lives into fatalities.

Although various factors, including patient- and community-specific factors and changes in social structures, are involved in prolonging on-scene time, no previous study has examined the entire range of factors at once, making it difficult to address the problem. Cities that provide broad-based critical care activities in densely populated areas, such as the Tokyo and Osaka metropolitan areas, are likely to face problems associated with longer emergency service time, whereas Fukuoka City and other smaller cities tend to provide critical care activities smoothly within a given area.

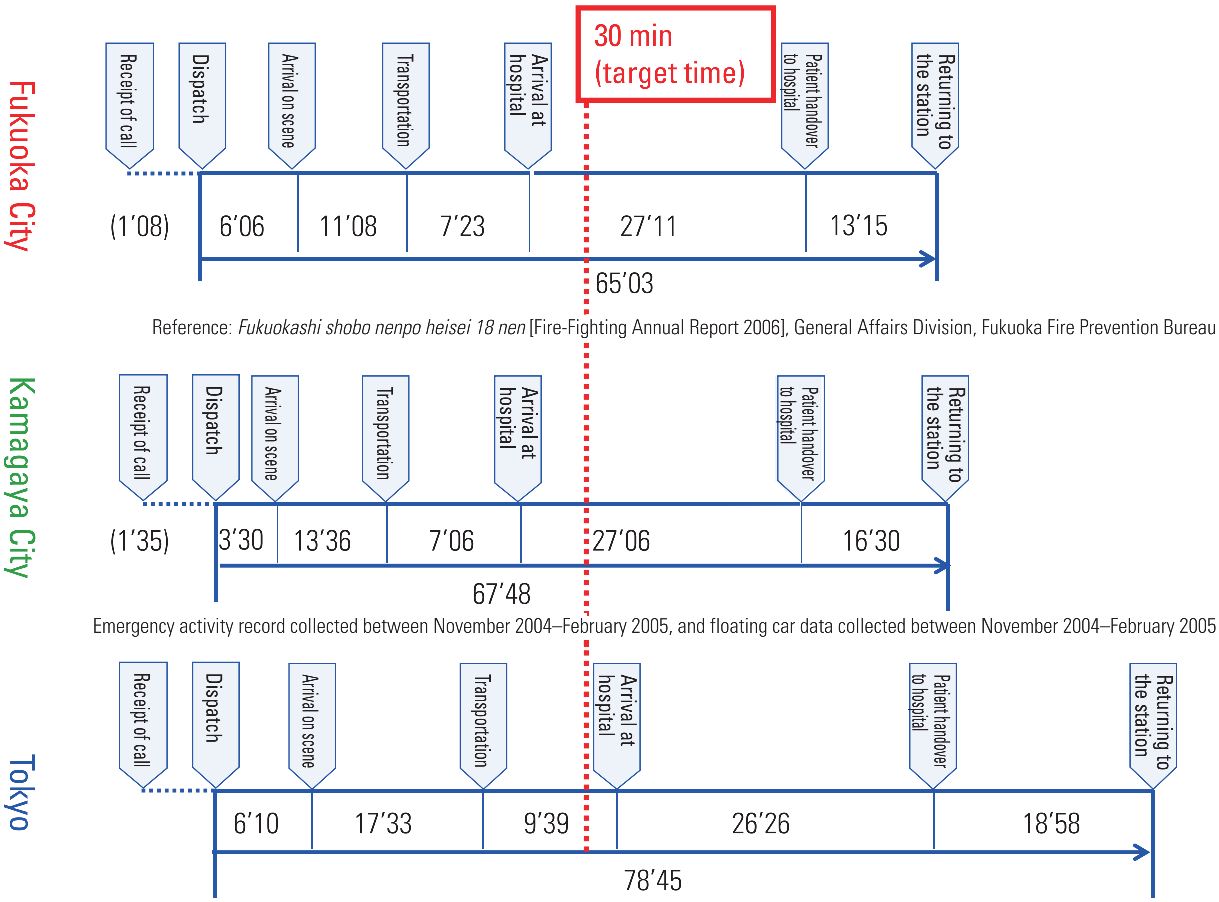
The aims of this study are (1) to reveal issues associated with prehospital ambulance transportation by using objective floating car data on ambulance transportation to develop effective measures and (2) to investigate the case where injured or diseased patients are transported from hospital to hospital due to each one refusing to accept them by comparing differences in emergency care services between cities with and without such problems. Findings from these studies will allow us to recommend solutions to performing effective prehospital critical care activities in much broader areas in the future.

2. Research content

2-1. Comparisons of critical care activities among cities of different sizes

To reveal the differences in critical care activities among cities of different sizes, we analyzed actual care activities provided in Tokyo , Fukuoka City, Fukuoka Prefecture, and Kamagaya City, Chiba Prefecture (Fig. 1). Although the size of Fukuoka City is somewhere between that of Tokyo and Kamagaya City, individual emergency response teams in Fukuoka City are responsible for a larger population and a wider area. Travel time between dispatch and arrival on scene was shortest with Kamagaya City. However, Fukuoka City had the shortest on-scene time, which was 6 min 25 sec shorter than on-scene time

Project Leader: Takashi Moriya
Professor, Emergency Department, Saitama Medical Center, Jichi Medical University



Reference: *Heisei 18 nen kyukyu katsudo no gaiyo* [Outlines of Emergency Activities in 2006], Emergency Management Division

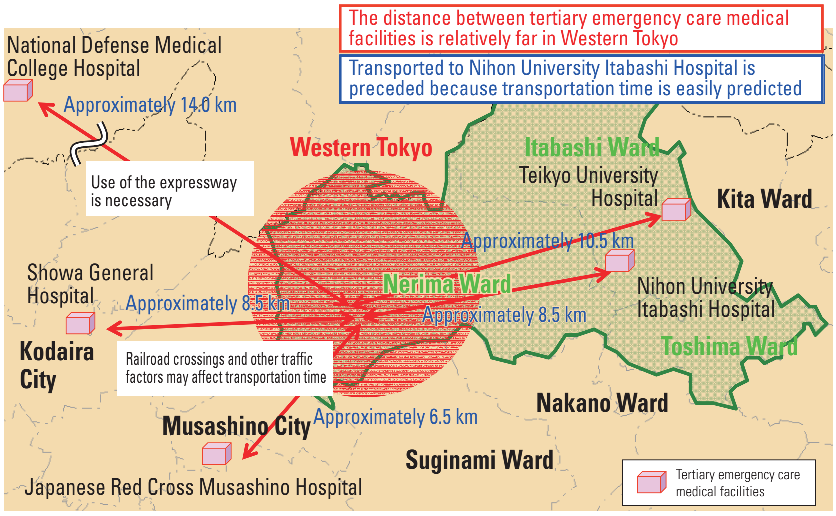
Figure 1. Comparisons of current critical care activities provided in Fukuoka City, Kamagaya City, and Tokyo The target time between dispatch and arrival at hospital is 30 min.

required in Tokyo. Tokyo also had the longest transportation time.

2-2. Current situations in critical care activity provided to high acuity patients during transportation

Analysis of emergency care service data collected at the Critical Care Center of Nihon University Itabashi Hospital,[(1)] Tokyo, revealed that (1) transportation time is excessively long in certain areas, (2) rapid transportation is prevented by narrow streets and railroad crossings where gates remain lowered for an extended time, and (3) there are only a small number of secondary emergency care facilities equipped and designated for providing care to moderate acuity patients in Tokyo. This results in patients having to be transported to tertiary emergency care medical facilities, which provide care to high acuity patients requiring admission to an intensive care unit, because their conditions deteriorated while the

(1) The Critical Care Center of Nihon University Itabashi Hospital is a tertiary emergency care facility for treating patients facing critical situations. Patients in less serious condition, but who still require inpatient treatment or emergency surgery, are treated at secondary emergency care medical facilities.



The distance to a tertiary emergency care facility is a straight distance from Shakujii Park, which is located almost mid-way between the Oizumi and Shakujii districts.

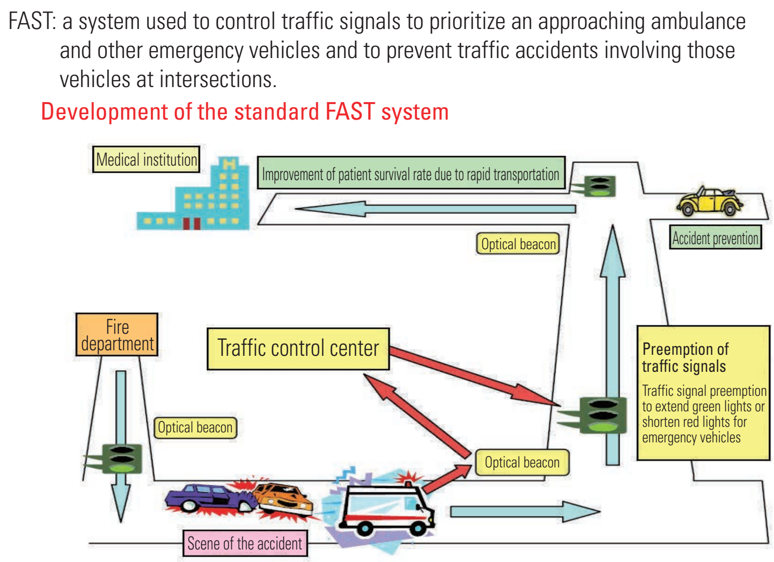
Figure 2. Problems associated with the area covered by individual tertiary emergency care medical facilities

emergency response teams were traveling from hospital to hospital in search of an appropriate destination (Fig. 2).

2-3. Example of cities that operate a smooth emergency care system

In contrast, some cities provide efficient emergency care services. For example, Fukuoka City utilizes a Global Positioning System to locate an emergency response team, which displays the address to shorten the time to locate the scene, utilizes information on traffic and hospitals' preparedness to accept emergency patients, and relocates emergency response teams if they are unevenly distributed in a given area to reduce travel time, on-scene time, and transportation time.

Kanazawa City has incorporated a traffic signal preemption system for emergency vehicles (Fast Emergency Vehicle Preemption System (FAST)) to streamline the city's emergency services (Fig. 3). In the areas where the FAST system is in place, the speed of emergency vehicles has been improved, travel and transportation time has been shortened, and the emergency service area covered by each response team has been expanded.



Reference: *Shobo no ugoki* [Current Developments in Fire and Disaster Management], No. 440, Fire and Disaster Management Agency, November 2007

Figure 3. Fast Emergency Vehicle Preemption Systems (FAST) in Kanazawa City

3. Conclusions

A close association between fire departments, on-scene emergency response teams, and hospitals is the key to proper critical care activities. To improve the rate of life-saving emergency services, it is of paramount importance to shorten and tighten the links between the three divisions in the critical care triangle (Fig. 4). This can be achieved by shortening time for travel, on-scene prehospital care, and transportation. In search of solutions, we investigated the current situations and challenges of critical care activities provided in three cities.

The findings of this study showed that the time required to locate the scene and to arrive on scene can be effectively shortened by the establishment of a proper emergency management system or by the incorporation of FAST, and that emergency transport time can be reduced by appropriately placing regional secondary emergency medical facilities. Successful critical care activities cannot be achieved only by establishing information systems or by streamlining emergency hospitals. It is important to develop a critical care system that is appropriate for the size of each community to build close working relationships and foster highly sophisticated collaboration between emergency management centers, emergency response teams, and physicians.

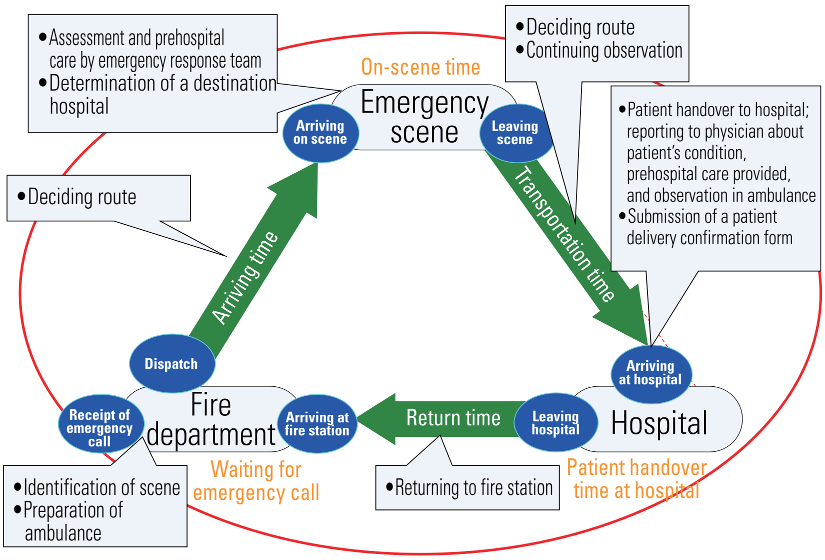


Figure 4. Critical care triangle

Issues that need to be addressed include the incorporation of the command and control system, the investigation of effective wide-based emergency services, and the determination of how the FAST system would improve emergency transportation. Furthermore, it is important to develop measures in the event of hospitals' refusal to accept emergency patients in order to improve hospital acceptance rates.

4. Future outlook

The prolongation of time required for emergency care response and transportation is a serious problem even in local cities. On-scene time is also anticipated to increase due to the expansion of prehospital care. It is therefore important to establish an effective multidisciplinary cooperation system between physicians, nurses, administrators, the police, the fire department, emergency services, and the government.

Dissemination and promotion of screening for sleep disorders

1. Background and goals

Sleep apnea syndrome (SAS)[(1)] is a pathological condition characterized by intermittent episodes of loud snoring and a pause in breathing (i.e., apnea) due to upper airway obstruction by the tongue sliding into the back of the throat. This results in shallow sleep and insufficient oxygen supply to the brain, so individuals with SAS are unable to obtain sufficient sleep, experience excessive daytime sleepiness, and easily fall asleep, resulting in low concentration and a high incidence of accidents due to careless driving and falling asleep at the wheel.

Several million people are estimated to have SAS in Japan. Even though continuous positive airway pressure (CPAP)[(2)] therapy has been established to treat SAS, only about 300,000 patients are currently treated by CPAP. This is in part because sleepiness due to SAS can be easily mistaken as an age-related chronic fatigue symptom, and also because many individuals with SAS do not readily feel sleepy after living with chronic sleep loss for years and therefore do not consult a physician, leaving SAS untreated. Against this background, a first step would be to establish a system to screen individuals with SAS who require further treatment. However, it is impossible to impose the burden of comprehensive testing on every person who is suspected of having SAS because a definitive diagnosis of SAS requires elaborate and costly overnight testing at a specialized medical facility. For this reason, a simple screening system is required to narrow down those individuals who need comprehensive testing. This study aims to develop and disseminate an SAS screening test and promote the treatment of SAS.

2. Research content

2-1. Special seminar on sleep-disordered breathing

In 2012, at the Nara Trucking Association, the International Association of Traffic and Safety Sciences hosted a special seminar entitled "Sleep-Disordered Breathing and Health Problems among Truck Drivers" and provided comprehensive information about SAS to trucking business owners, health

Project Leader: Takeshi Tanigawa
Professor, Department of Public Health, Graduate School of Medicine, Juntendo University

(1) Sleep apnea syndrome (SAS): a disease characterized by episodes of apnea during sleep. Apnea is defined as a pause in breathing that lasts more than 10 seconds. SAS is diagnosed when apnea occurs more than 5 times in 1 hour or 30 times in 7 hours during sleep.

(2) Continuous positive airway pressure (CPAP): a method used to prevent airway obstruction by sending pressurized air (positive airway pressure) via a tube to a mask worn on the nose in order to compress the soft tissues surrounding the root of the tongue and thereby open the airway.

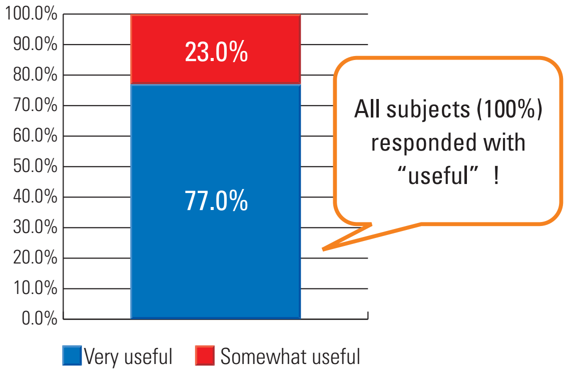


Figure 1. Impact of the special seminar

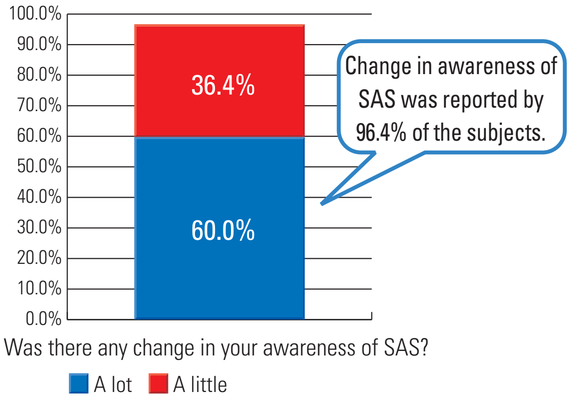


Figure 2. Change in awareness of sleep apnea syndrome

supervisors, and truck drivers. A survey conducted after the meeting revealed that the meeting was an excellent learning experience for the attendees (Figs. 1, 2).

2-2. Administration of a screening test

After the seminar, attendees were recruited for an SAS screening test, and the openings for 200 test subjects were filled in just 3 days, revealing high levels of interest in SAS among meeting attendees.

In this study, a flow sensor, used as a simple tool to monitor breathing and screen for SAS, was mounted over the nose and mouth to examine for apnea and hypopnea during sleep based on the degree and frequency of changes in air flow (Fig. 3). The notable feature of this testing is that SAS screening can be performed at home using a small take-home device with a little burden on the subject.

Figure 3. Simple diagnosis with a flow sensor

In addition to the use of a flow sensor, a self-administered questionnaire survey was performed in order to look for a correlation between SAS and perceived sleep quality. This questionnaire is the Japanese version of the Sleep Disorders Screening Survey used at Harvard University in the United States and employs the Epworth Sleepiness Scale as a measure of daytime sleepiness and also asks about subjects' sleep and driving patterns.

2-3. Results

(1) Subjects

The survey results showed that 48 subjects (24%) were living with moderate to severe sleep-disordered breathing. The severity of respiratory disturbance was positively correlated with the degree of obesity but not with other factors, such as age, smoking or drinking habits, blood pressure, and neck circumference.

(2) Association between subjects' experiences and sleep-disordered breathing

Many subjects with a high respiratory disturbance index had suspected in the back of their mind that they had SAS or narcolepsy. Moreover, a relatively large number of subjects had been informed about their apnea or snoring even by someone who was in the next room. Respiratory disturbance index was not significantly correlated with the sleepiness scale score.

(3) Sleepiness and severe sleep-disordered breathing

The findings of this study revealed that more than 90% of the subjects with sleep-disordered breathing did not actually experience intense daytime sleepiness.

2-4. Comprehensive testing

Diagnostic criteria for SAS are based on polysomnography (PSG)[(3)] testing. PSG evaluates the quality and amount of sleep by using numerous sensors and electrodes to measure air flow in the nose and mouth, snoring, arterial oxygen saturation, breathing motion in the chest and abdomen, and posture (Fig. 4). A special examination room and a technician trained in PSG are needed to conduct PSG, and therefore, it is not only costly but also time-consuming and a large burden on patients.

Although 13 subjects were suspected of having severe SAS according to the screening test conducted by the Nara Trucking Association, only 2 of them subsequently underwent PSG (Fig. 5). This outcome stands in sharp contrast to the high levels of interest in SAS shown by the subjects prior to the screening test, most likely reflecting the large burden imposed by PSG.

PSG involves electroencephalography as the major component, electrooculography, electrocardiography, and the measurements of breathing patterns, peripheral blood oxygen saturation, and body posture. PSG requires a special examination room, a technician trained in PSG, and skills in data recording and analysis.

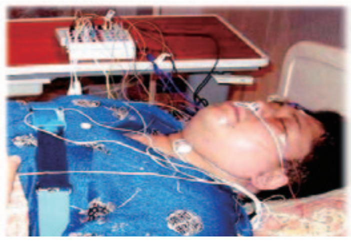


Figure 4. Overnight PSG: a time-consuming and costly definitive diagnostic method for SAS

SAS screening of 200 subjects

Screening test results

Grade A:	2 subjects (1%)
Grade B:	26 subjects (13%)
Grade C:	76 subjects (38%)
Grade D:	35 subjects (18%)
Grade E:	13 subjects (6.5%)
Unable to grade:	40 subjects (20%)
Cancellation:	8 subjects (4%)

Outpatient Sleep Clinic, Tenri Municipal Medical Center

Number of contacts:	4 subjects (2%)
Appointment for PSG:	2 subjects (1%)
PSG performed:	2 subjects (1%)

Figure 5. Approach taken by the Nara Trucking Association

3. Conclusion

In this study, a special seminar was offered to trucking business owners, health supervisors, and truck drivers affiliated with the Nara Trucking Association,

---

(3) Overnight polysomnography (PSG): an overnight screening test performed on admission to a special examination room to examine sleep patterns by using electroencephalography, electrooculography, and electromyography of the mentalis, as well as breathing patterns by collecting data on airflow through the mouth and nose and the movement of the chest and abdomen. PSG is used to determine the severity of SAS and the appropriate treatment.

followed by a questionnaire survey and screening test administered to approximately 200 truck drivers. In this way, we attempted to establish a system with the following flow: awareness-raising about SAS screening → screening test → comprehensive examination and treatment.

With regard to the correlation between sleep-disordered breathing and daytime sleepiness, more than 90% of the present subjects with moderate to severe sleep-disordered breathing answered that they did not experience daytime sleepiness. This clearly indicates that subjective tests are not enough to screen for SAS, and therefore, more objective screening tests, such as the flow sensor method, are needed to detect individuals with undiagnosed SAS. This study also suggests that society as a whole needs to be aware of SAS because some aspects of the disease cannot be addressed by individuals who have SAS.

4. Future outlook

The awareness-raising activity presented in this study is an example that can be applied to any region across Japan. Our goals are to develop and disseminate an effective SAS screening system and to reduce the number of traffic accidents via the promotion of early detection and early treatment of sleep-disordered breathing. In collaboration with the relevant administrative agencies, we will also recommend approaches for the early detection of sleep disorders for which awareness among drivers is low.

Creating installation guidelines for tactile ground surface indicators (braille blocks) for the visually impaired

1. Background and goals

Tactile ground surface indicators for the visually impaired, also known as braille blocks, were invented in Japan in 1965. Since then, braille blocks have been installed not just in Japan but throughout the world. It is gratifying to see the growing number of installations, but because they have spread without clear installation guidelines and methods in place, there are currently a number of installations around the world that are dangerous, pose barriers to other pedestrians, or do not serve their intended function. Another problem is that braille blocks are being manufactured according to the unique rules of various regions, so there is a lack of design uniformity. There are even cases within Japan where specific areas are installing blocks according to local rules. This situation has made clear the necessity of establishing installation guidelines that can be used both in Japan and overseas for braille blocks to be utilized by visually impaired persons. The goal of this project is to elucidate problems related to the installation of braille blocks currently in use, prior to the establishment of such guidelines.

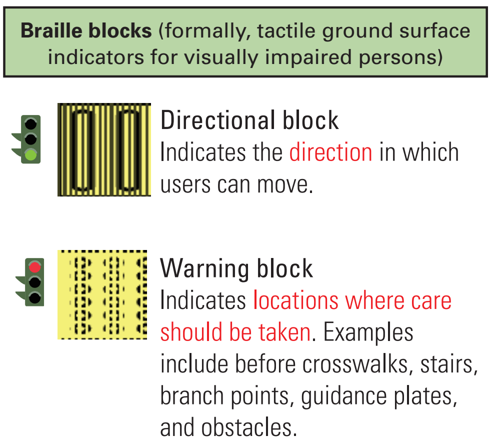


Figure 1. A directional block and a warning block

Figure 2. Dissimilar braille blocks

Project Leader: Katsumi Tokuda
Professor, Faculty of Medicine, University of Tsukuba

2. Research content

Evaluation experiments were performed with visually impaired participants who are the intended users of braille blocks, and areas needing improvement were summarized. Questionnaires and interviews were also conducted to investigate the impact of braille blocks on other pedestrians (in particular wheelchair users, the elderly, stroller users, young children, etc.) and to elucidate needed improvements.

2-1. Evaluation experiments with visually impaired participants

Example where no warning block has been installed at a crosswalk entrance (Sapporo City)

Example of an overly narrow warning block (Nagasaki City)

Example of erroneous installation positioning (Nisshin City, Aichi Prefecture)

Example where no warning block is installed at an intersection of directional blocks (Saga City)

Example where no warning block is installed at an intersection of directional blocks (Toyama City)

Figure 3. Inappropriate placements of warning blocks

The evaluation experiments with visually impaired participants were conducted in order to investigate the matters that only users can evaluate, such as the placement of warning blocks before obstructions, the angle of warning blocks placed before changes in the direction of continuous directional blocks, dangers posed by blocks and rules used in only certain locales, and the necessity of installing directional blocks that indicate directions in front of intersections. Most experiments were performed using temporary braille block installations on the University of Tsukuba campus, but in some special cases experiments were performed at actual installation sites.

The following results were obtained. (1) Warning blocks should be installed in cases where the direction of directional blocks will bend with an interior angle of 135° or less. (2) Ministry of Land, Infrastructure, Transport and Tourism guidelines specifying that warning blocks should be installed 30 cm in front of potential hazards are appropriate. (3) Some blocks used in accordance with local rules are incapable of providing appropriate warnings. In particular, situations where warning blocks conforming to JIS standards are mixed with directional blocks conforming to local rules are extremely dangerous, and urgently require improvement.

2-2. Braille blocks as a barrier to wheelchair users and other pedestrians

Interviews and questionnaires were conducted with pedestrians for whom braille blocks may pose a barrier, such as wheelchair users, the elderly, stroller users, and those with small children.

In a survey of wheelchair users, 72% responded that they regard braille blocks as a barrier. In a survey of walking aid users, 85% reported that it is difficult to pass over braille blocks. One respondent reported trying to avoid braille blocks as much as possible, but in some locations, tiles are so pervasive that they are impossible to avoid.

Most stroller users (82%) reported the stroller getting caught up on braille blocks. There were also reports that the vibrations caused by passing over braille blocks are strong enough to wake a sleeping child. In a survey of guardians of small children, 50% reported cases of children stumbling and tripping over braille blocks. One respondent reported a case where a two-year-old child tripped on braille blocks, resulting in a large bump on the child's head.

The above indicates the necessity of methods for installing braille blocks that do not pose a barrier to other pedestrians.

3. Conclusions

On the basis of the results presented above, we have created Japanese and international editions of the *Guidebook for the Proper Installation of Tactile Ground Surface Indicators (Braille Blocks): Common Installation Errors* as a supplement to the installation guidelines from the Ministry of Land, Infrastructure, Transport and Tourism. We have also held information sessions at approximately 40 domestic institutions and facilities, as well as 15 overseas institutions.

In the future, we will more widely distribute the guidebook that we created, along with additional explanations as necessary. We hope to continue working toward further optimization of braille blocks, both in Japan and abroad.

Installation rules for directional blocks

- Directional blocks should be installed in locations where there are no potential hazards within 30 cm to the sides or overhead.
- Directional blocks should allow for easy recognition of indicated movement directions.
- Directional blocks should guide users to necessary locations.
- Directional blocks should maintain continuity.
- Warning blocks should not be installed before bends with an interior angle of 135° or more.
- Tiles should be of sufficient surface area to allow tactile recognition through shoe soles.

Installation rules for warning blocks

- Warning blocks should be installed in locations sufficient to allow users to stop before obstructions (30 cm in front of obstructions)
- Warning blocks should clearly indicate path branches.
- Warning blocks should allow easy recognition of the meaning of the warning.
- Tiles should be of sufficient surface area to allow tactile recognition through shoe soles.

An example of an installation improvement given in the guidebook

Directional blocks must maintain continuity. Manholes are a common reason for interrupting the continuity of directional blocks. In such situations, directional blocks should also be installed on top of the manhole.

[An example of an installation improvement]

4. Future outlook

As of April 2014, we have completed field investigations in 101 countries and regions. Braille blocks have been installed in many countries and regions, but we identified many errors in those installations. We have presented this information through reports and oral presentations at various international conferences. We have also responded to requests for advice regarding braille block installations in several countries, including Turkey and Israel. In the future, we hope to make whatever efforts we can toward worldwide unification of installation methods for braille blocks. Our book *Tenji burokku* [Braille blocks], which is based on the results of our activities at the IATSS and follow-up research, won the 2013 Mitsui Sumitomo Insurance Welfare Foundation Award.

Ensuring urban public transportation mobility for people with intellectual disabilities

1. Background and goals

As of the end of 2006 there were around 550,000 persons diagnosed with intellectual disabilities in Japan, accounting for approximately 0.4% of the population.

The Law for Buildings Accessible to and Usable by the Elderly and Physically Disabled Person and the earlier version of the Transportation Barrier-Free Law were combined into the Law for Promoting Easy Mobility for the Aged and the Disabled Person, which went into effect in December 2006.

Due to these policies, various handbooks and guidelines related to human response and facilities development have been published, but in many cases these resources remain unknown to transportation operators in the field. This has led to insufficient addressing of issues related to persons with intellectual disabilities.

Against such a background, this project was formed and research began in 2011 with the goal of examining policies related to international trends in ensuring mobility for persons with intellectual disabilities, and thereby uncovering issues needing to be addressed in Japan.

2. Research content

2-1. International case study 1: SITES (Curitiba, Brazil)

The SITES handicapped student bus system, started in Curitiba, Brazil in 1983, uses standard buses incorporated into an established transit system. In that system, buses from various locations in the city arrive at a connecting terminal in the northeast downtown area at a time. Students board buses at the stop closest to their home and head for the connecting terminal. Students from all schools use the buses and students with a variety of handicaps share the same system. At the connecting terminal, they can change to buses heading for their

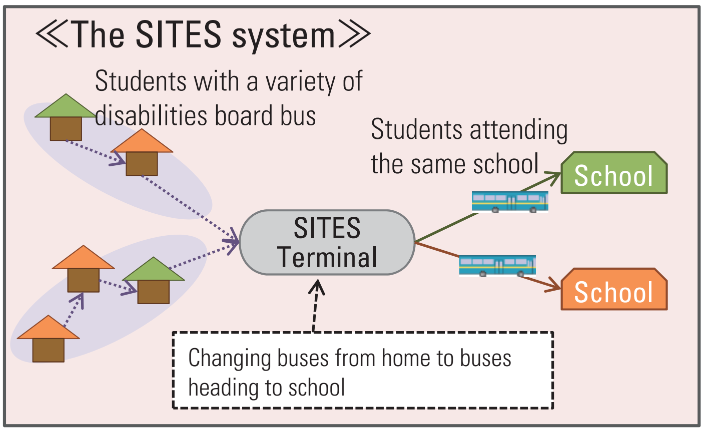


Figure 1. The SITES system

Project Leader: Fumihiko Nakamura
Professor and Dean, Institute of Urban Innovation, Yokohama National University

individual schools.

Interviews were conducted with intellectually disabled students changing buses at the SITES terminal, as well as personnel, such as bus drivers and accompanying guides. This resulted in new findings, including that there was little trouble related to changing buses and that the system presented a platform for exchange that leads to increased sociability in participants.

2-2. International case study 2: The MogLi project (Germany)

MogLi is a research project supported by the German Federal Ministry of Education and Research related to mobility for the intellectually handicapped. The project targets special needs schools in the town of Nordhorn and their students. The project began an experimental attempt to utilize chartered buses for students, in which bus operators and local police serve as guides. After verification experiments were complete, the system was put into place, and guided busing is now performed on a regular basis.

Figure 2. Explaining how to ride the bus to school

2-3. Domestic experiment 1: Stop mark display experiment

Installing stop marks for students is ineffective without accompanying education regarding the meaning of those signs; unknowing students will simply pass by without heeding them. We therefore performed an experiment in which student-oriented stop marks were installed in the vicinity of target schools for three months, and during a field trip, the meaning of the signs were explained to students. This experiment had two goals: elucidating the effect of pre-education including field trip-based class instruction regarding stop marks to students at special needs schools, as well as finding issues related to class instruction on stop marks.

The experiment targeted elementary and junior high students who commute by school bus, not high school students who were able to travel to school on their own.

We were able to see results in post-interviews with school personnel, but for only a few months after the experiment, and thus were not able to observe improvement of students' understanding beyond that. However, we expect that continued education will result in students' increased learning of traffic rules.

Figure 3. A stop mark

2-4. Domestic experiment 2: Commuting to school by city bus

With the goal of elucidating the effects of educating city bus guidance involving transportation operators and issues related to performing such education, on January 10, 2013 we performed an experiment with the cooperation of the Seya *Yogo* School (*Yogo* being a Japanese term used in special needs education) in Yokohama, Kanagawa Prefecture, related to bus guidance that targeted students at that school. The contents of instruction are shown in Table 1.

Table 1. Contents of instruction regarding city buses

Item		Method in the experiment
External safety	Explanation of blind spots	Showing dangerous spots at an actual bus stop
	Lining up at the bus stop	Lining up before actually boarding the bus
Getting on and off	Reading destination displays (destination, route number)	Creating a destination (route number) game to explain which buses should not be ridden
	Reading in-bus electronic displays (stop name)	Verbal description while watching the board display
	Description of the stop button	Verbal description (including when to press), followed by one student pressing button
	How to show tickets and bus passes	Explanation of bus passes and prepaid cards, experience showing bus passes to driver, and using card reader for prepaid cards
Safety in the bus	When to stand up	Verbal cautioning
	Points to follow while standing in the bus	Verbal cautioning to hold on to handrails and straps
Manners	Taking turns getting on the bus	Verbal cautioning; actually performing getting on the bus in turn
	Explanation of priority seating	University student volunteers perform the role of injured persons.
	How to sit (when someone else is already sitting)	University student volunteers perform the role of general passenger; describe sitting in an empty seat
	Not making noise, not running	Verbal cautioning

Interviews conducted after the experiment indicated that students hearing explanations by uniformed bus drivers or transportation operators had a greater impact than did those delivered by educators or guardians, allowing listeners to better retain the presented information and to recall it when conducting busing guidance.

2-5. Domestic experiment 3: Commuting to school by automated guided transit

It is possible that students who are able to travel to school on their own via public transportation also use automated guided transit. We therefore conducted a similar experiment to examine whether students at a domestic special needs school could commute to school via line A on one such automated metro. The experiment was conducted on February 19, 2013 with 26 student participants. The contents of instruction are shown in Table 2.

In post-interviews conducted with *Yogo* school educators, the following comments were noted:

- The difficulty level was low, since students are already able to get to school by themselves. For other students who are not able to get to school by themselves; however, experiential demonstrations would likely be required over verbal explanations.
- Students would likely better understand explanations given in stopped cars or in the station, rather than on moving cars.

Table 2. Contents of instruction regarding automated metro

	Item	Explanation and teaching methods
Outside safety	Cautions about platform doors	Verbal cautioning about running to board cars, getting caught in doors, etc.
Getting on and off	Reading electronic displays	Verifying arrival time
	Description of arrival platforms	Verbal confirmation of which station different lines are heading for
	Passing through ticket gates	Explanation and confirmation of prepaid card reader locations
	(How to use ticket vending machines)	Verbal instruction to give depleted prepaid cards to parents and teachers to be recharged
In-car safety	Points to follow when standing from seats	Verbal cautioning
	Points to follow while standing in the car	Verbal caution to hold on to handrails and straps
Manners	Taking turns getting on the car	Verbal cautioning; actually performing getting on the car in turn
	Waiting on the platform	Verbal cautioning to not make noise, and to not run; verification of waiting in line.
	Description of priority seating	University student volunteers perform the role of injured person
	How to sit (when someone else is already sitting)	University student volunteers perform the role of general passenger; describe sitting in an empty seat
	How to spend time in the car	Verbal cautioning to not make noise, not run
Other	Handling emergencies	Description of the intercom call, confirmation of the location of station staff

3. Conclusions

This project addressed issues in commuting to special needs schools by examining case studies overseas and by performing verification experiments in Japan based on those overseas findings.

Working to further support the mobility of intellectually handicapped persons in the future will not be possible without the support of not only schools, but also transportation operators, road management personnel, and transportation managers. A future topic is therefore the awareness building activities and the development of systems for promoting common understanding among transportation officials.

4. Future outlook

We hope that the results of this research lead to deeper communications between schools for students with intellectual disabilities throughout Japan and area transportation operators, the further expansion of various verification experiments, and furthered accumulation of knowledge.

A study on the level of service for local public transport to secure basic daily life

1. Background and objective

Maintaining public transport services is not an easy task for local community, especially in rural areas. Residents who are unable to use private cars feel difficulty in taking opportunities for the minimum activities necessary for daily life, such as commuting to work or school, visiting shops, and going to the hospital. Faced with financial constraints, a question of where and to what extent public transport services should be secured and maintained is a significant concern for those responsible for local transport policy.

To determine the level of service for public transport that should be secured, it is necessary to define an ideal state of the local community and clarify the role of transport to achieve it. However, no sufficient methodology to this end has been established.

Accordingly, this project was implemented to create a method for determining the level of service for public transport that a local community should secure and to develop a methodology by which to formulate a local public transport plan as the basis of these services.

2. Methodology and field study

2-1. Significance of local public transport planning and necessity of planning methodology

The number of users of public transport has decreased along with the progress of motorization, and public bus services are no longer profitable in regions where car usage has become widespread. The fact that services essential to society are not sufficiently provided when left to private businesses suggests that local public transport should be regarded as social infrastructure.

What changes when securing and maintaining local public transport are treated as improvements of social infrastructure? The change is the resulting necessity of planning. For example, planning is implemented when developing social infrastructure, such as river and road improvements. The reason for implementing this planning is to demonstrate that the scheduled improvement will be efficient and effective, and to build social consensus, because the improvement of social infrastructure will be carried out by a public entity and funded by taxes. In other words, this is planning with a public intent. However, while there are business plans for local public transport decided by companies, almost no transport

Project Leader: Hideyuki Kita
Professor, Division of Civil Engineering, Graduate School of Engineering, Kobe University

plans are decided as social infrastructure improvement plans. One possible reason for this is a lack of planning methodology. Herein lies the significance of constructing a planning methodology by which to establish the level of service for local public transport in this project.

2-2. Framework

When determining the level of service for public transport, the level that should be secured cannot be decided unilaterally. Stipulations such as operating a certain minimum number of buses per day are not meaningful per se. Instead, the basic index is the amount of opportunities for activities that can be secured via the operating buses. Furthermore, in the event that the municipality improves the public transport service, the improvements need to be based on the decision of residents as both taxpayers and users of public transport. The budget constraints of the municipality are limited according to the tax burden of the residents, and so the administration should determine the kind of public services that are necessary and the level of increase in tax burden that residents would permit in return, reflecting this in the budget. In this project, we established a review framework for the local public transport plan as shown in Fig. 1, recognizing the importance of the idea that residents select the combination of opportunities for activities to be secured and the associated tax burden.

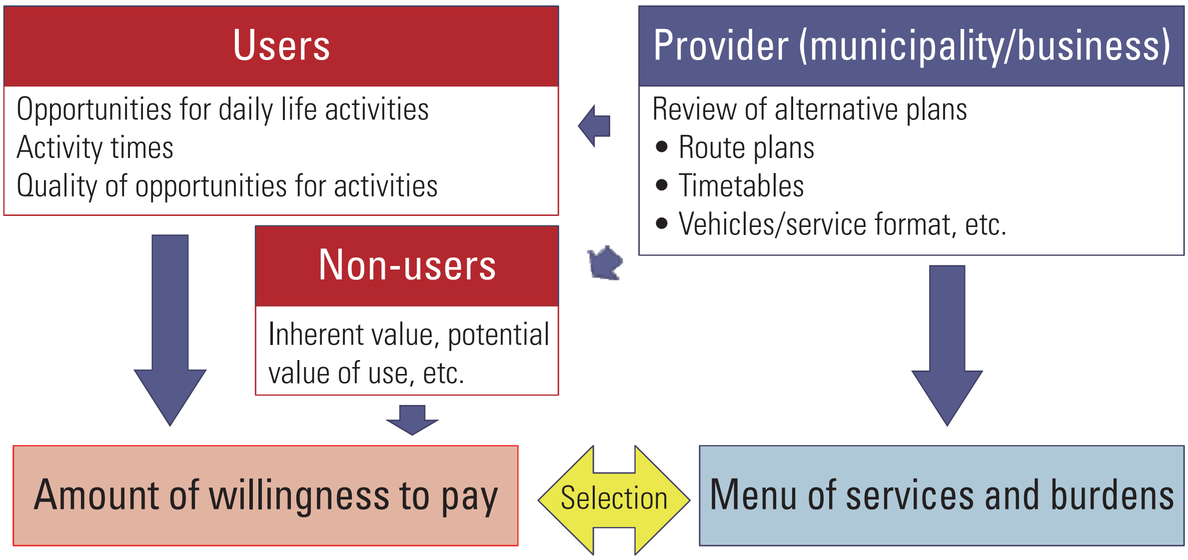


Figure 1. Review framework for the local public transport plan

2-3. Planning methodology for local public transport

(1) Overall structure

Local public transport planning is the selection and proposal of the most desirable public transport system for the region. To this end, three stages are necessary: (1) demonstrate the

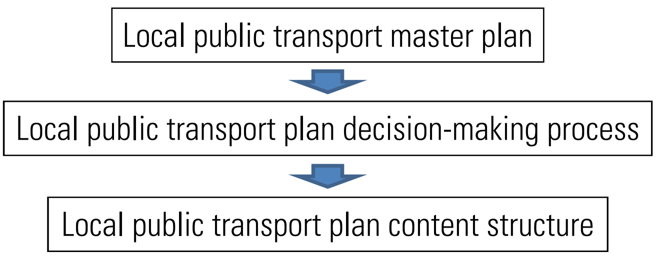


Figure 2. Overall structure of the local public transport plan

way of thinking by which the desired public transport system is selected, (2) select a desired public transport system, and (3) present the outcome of the selection. In this project, we proposed a planning system comprising the three elements shown in Fig. 2.

(2) Local public transport master plan

The local public transport master plan is the declaration of the intent to create a local public transport plan. Table 1 shows the necessity of planning and shows the stance of the municipality formulating and promoting the plan as policy.

(3) Decision-making process and structure of local public transport plan content

The process for deciding the local public transport plan is systematically organized so that all details that must be considered to formulate a better plan are presented. Here, it is necessary to list proposals for consideration in full and have the local residents select the best proposal according to the relationship between the benefit returned and the tax burden. The organization of the content of the local public transport plan (Table 2) presents a structure for when the results of the investigation carried out based on the decision-making process and the service provision plan selected are summarized as a local public transport plan. We therefore consider this to illustrate one of the standard forms of the local public transport plan.

Table 1. Local public transport master plan

1. Identification of the structure of exchanges among people in the local community
2. Image of a mobility plan for the people in the local community
3. Basic policy for securing public transport
4. Public body's declaration to promote public transport policy
5. Policy for the effective administration of public transport services
6. Appeal for the mobilization (cooperation) of local residents
7. Basic stance toward local public transport planning

Table 2. Structure of public transport plan content

1. Background to the plan
2. Verification of the local public transport master plan
3. Decision and zoning of service provision standards
3.1 Framework of the plan
3.2 Local characteristics
3.3 Structure of the region and basic structure of the public transport network
3.4 Opportunities for activities that should be secured
3.5 Service provision standards for each zone
4. Service provision plan
4.1 Transport services
4.2 Form of services
4.3 Route network plan
4.4 Region-specific service plans
4.5 Fare/local tax burden
4.6 Service costs/improvement of efficiency
5. Public procurement plan
5.1 Estimation and classification of profitable/unprofitable routes
5.2 Selection of administration format
5.3 Selection of transport operator
6. Public commitment

2-4. Field study

To verify whether the planning methodology proposed in this project is effective and suitable for practical application, and to identify issues and points for improvement, a field study was carried out in Hirakawa City, Aomori Prefecture. The research group provided expertise and gave technical advice to a local colloquium, and the region offered progress and investigation results to the research group. At the colloquium, alternative plans were presented for the number of buses and the timetables necessary for daily life, the number of services operable within the limits of the subsidy, and the resulting passenger fares. A discussion was then held among the residents, who elected for a combination of a 200 yen fare and an increased number of services in comparison to the present 100 yen fare and 5 services. They went on to propose the scheduling of school buses and other such development.

In this way, the residents themselves were able to select the public transport services to provide opportunities for activities, confirming that the review framework was applicable, at least in this context. From the achievement of more favorable conditions for the residents than before and the greater ability of the municipality to provide public transport that meets the needs of the residents within the limits of financial constraints, the effectiveness of the review framework was also confirmed.

3. Conclusions

In the event of the municipality participating in the provision of public transport services, the municipality cannot unilaterally determine the level of service that should be secured, and it is only possible to select the level of service by deciding a local transport plan. Through research, we proposed the construction of a methodology for local public transport planning and a method for selecting the level of service. It was then confirmed that these were effective and suitable for application in practice. Based on these results, the research team is compiling guidelines for local public transport planning.

After the Act on Revitalization and Rehabilitation of Local Public Transport Systems was enacted in October 2007, many municipalities began formulating public transport plans. Future tasks are improving the methodology proposed in this project through implementation and applying it broadly. It may also be necessary to go beyond the provision of public transport, and to consider a comprehensive support strategy that incorporates the policies of various administrative departments.

Traffic safety and traffic enforcement

1. Background and goals

In 2012, the number of traffic accidents in Japan decreased for the eighth consecutive year to around 660,000. These accidents resulted in 4,411 fatalities, a reduction to approximately 30% of the peak in 1970. Although the downward trend in injuries continues, this year there have already been 820,000 people involved in traffic accidents, so accident prevention remains a significant problem. In particular, there is a need for further efforts to eradicate fatal accidents due to drunk driving.

In the past, traffic enforcement efforts have had some level of success in preventing traffic accidents. However, there seems to be no end to drivers who do not obey traffic rules. Cracking down on traffic violations and strengthening penalties can resort in a short-term reduction of traffic accidents, but they tend to return to their previous levels with the passage of time.

This study aims to provide a quantitative measure of the effect of traffic enforcement on reducing traffic accidents, and examines possible measures.

1-1. Research viewpoint and method

The embodiment of traffic enforcement has regional characteristics. For example, in large metropolitan areas there are often efforts to control parking violations and vehicle access violations, both of which most frequently occur in densely populated areas. By contrast, in less densely populated rural areas, efforts tend to be directed toward speed limit enforcement. There are also seasonal variations, such as speed limit enforcement being more concentrated during the summer in regions that receive heavy snow in winter. We therefore performed an analysis from the viewpoint of the regional characteristics of violators and violation enforcement.

2. Research content

2-1. Relation between traffic enforcement and traffic accidents

This section discusses whether traffic enforcement is effective in reducing traffic accidents. To give an example, a relational diagram is presented showing the number of traffic enforcement incidents per day and the number of traffic accidents per 1 million population in Tochigi Prefecture (Fig. 1). There were very few traffic enforcement incidents (e.g., 100 incidents per day or less) on days such as the New Year's

Project Leader: Akinori Morimoto
Professor, Faculty of Science and Engineering, Waseda University

holidays when little traffic was on the roads, and there were few traffic accidents on such days. Because of the existence of such atypical days, simply determining the correlation coefficient between enforcement and accidents would likely not give a clear relation.

However, we also found a tendency for the maximal number of traffic accidents to decrease as the number traffic enforcement incidents increases. The relational diagram clearly shows that the upper bound (95th percentile) on the number of traffic accidents is reduced as the number of traffic enforcement incidents increases. This tendency was the same in Okinawa Prefecture and Akita Prefecture. These results suggest that traffic enforcement has the effect of decreasing the number of frequent traffic accidents.

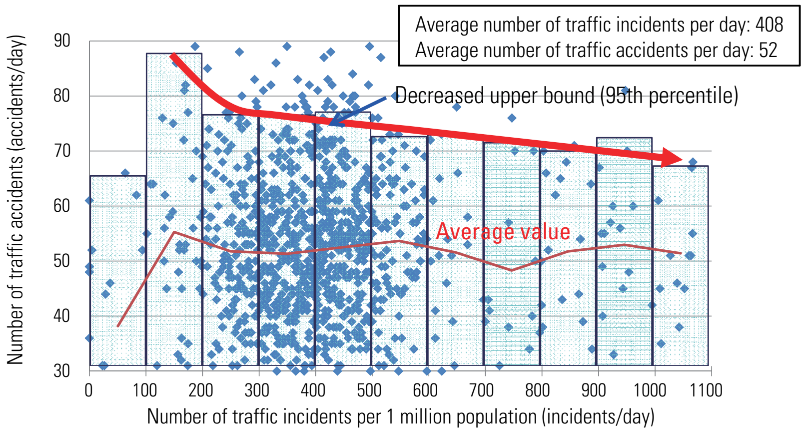


Figure 1. Relation between number of traffic enforcement incidents and number of accidents in Tochigi Prefecture

2-2. Violation history of first parties in traffic accidents

Next, the focus is turned to first parties in traffic accidents—the pedestrian or driver of the vehicle who bear the greatest responsibility for the accident—and the first party's history of past violations is considered.

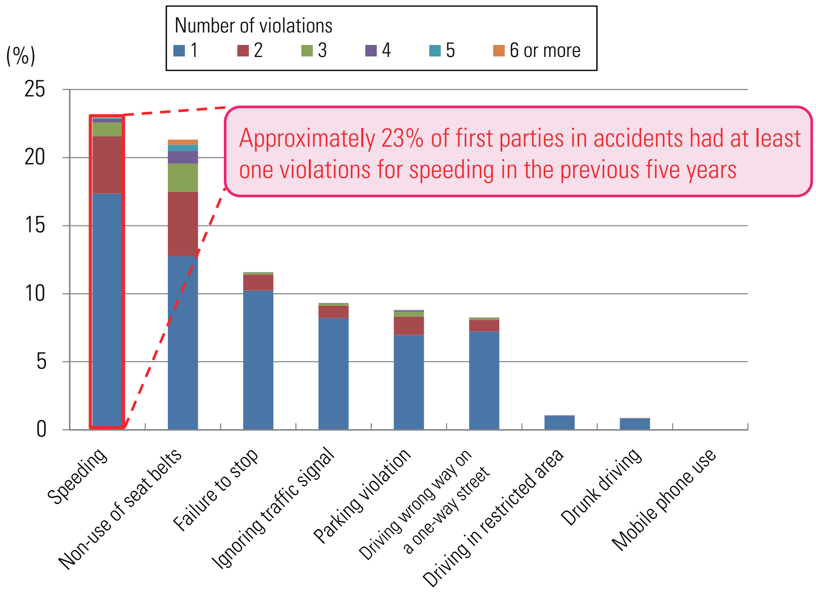


Figure 2. Violation history of first parties in accidents for the previous five years

Figure 2 shows of the types of traffic violations for which the first parties in accidents occurring in 2009 were cited during the five-year period 2004–2009. The violation histories show that 64% of male and 45% of female first parties had some type of traffic violation on record from the previous five years. Compared with second parties, the first parties had a higher violation rate for all types of violations. This seems to indicate that the driving etiquette of drivers who bear primary responsibility for accidents is worse than that of others involved in the accidents.

2-3. Regional trends in violations and their causes

To better understand the regional characteristics of serious traffic violations, we examined cities and prefectures with particularly high rates of repeated willful violations, such as ignoring traffic signals, speeding, and drunk driving (Fig. 3). Particularly notable were ignored traffic lights in Osaka and drunk driving rates in Okinawa. We discussed the latter finding with the Okinawa prefectural police, who gave the following reasons for the high rates of drunk driving:

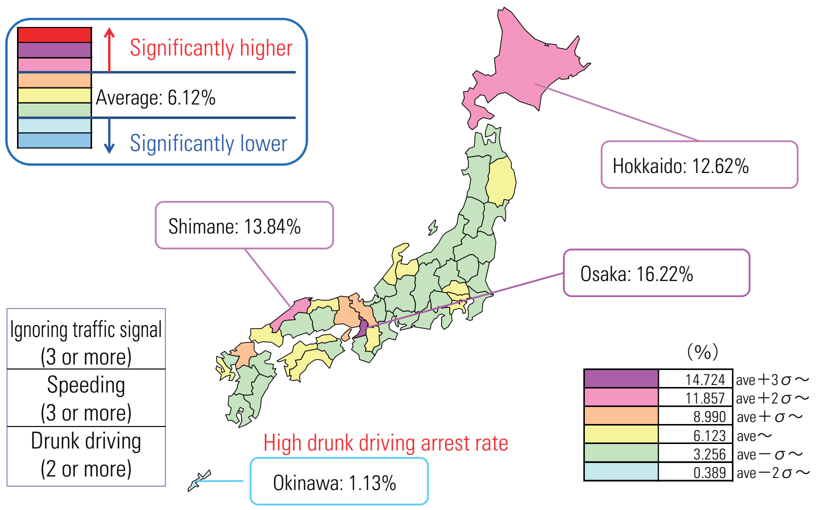


Figure 3. Percentage of repeated violations by first parties in traffic accidents

- Okinawan drinking culture: starting to drink at late hours, the popularity of *awamori* (a local beverage with a particularly high alcohol content), and the custom of passing drinks around.
- High reliance on automobiles because of lacking public transportation infrastructure and the prevalence of parking lots at drinking establishments.

To cope with this situation, efforts to combat drunk driving are concentrated between 2:00 and 6:00 a.m., when most accidents due to driving under the influence of alcohol occur. Moreover, since about five years ago, early-morning operations have been conducted to prevent driving with an alcohol hangover.

Such drunk driving enforcement efforts require significant time, and in recent years have become inefficient. There are limits to how much effort can be exerted, so ways to further reduce accidents is a topic requiring further study.

2-4. Planning efforts based on numbers of traffic accidents and violations

As a simple method for investigating the effect of traffic enforcement, we created a plot showing the number of traffic accidents and number of traffic enforcement incidents.

Figure 4 shows the relation between the number of traffic accidents and the number of traffic enforcement incidents by police station jurisdiction for individual town areas. The area covered is divided into four zones (1–4), based on the average number of citations issued and average number of traffic accidents.

Zone 3 has a low number of both citations and accidents. We therefore consider this area to be satisfactorily maintaining the status quo. Zone 4 has many citations and few traffic accidents. Areas in this Zone where traffic enforcement is considered excessive may therefore require policy revisions, and in areas where accident suppression is considered necessary, traffic enforcement efforts may need to be continued. Zone 1 has a many traffic citations but also many traffic accidents. Traffic enforcement efforts should continue in this area, but policies should also include consideration of other traffic safety measures such as improvement of the traffic environment. Finally, there were more traffic accidents in zone 2 than in the other areas but the number of citations was below average. This likely indicates a need to focus on strengthening traffic enforcement in this area.

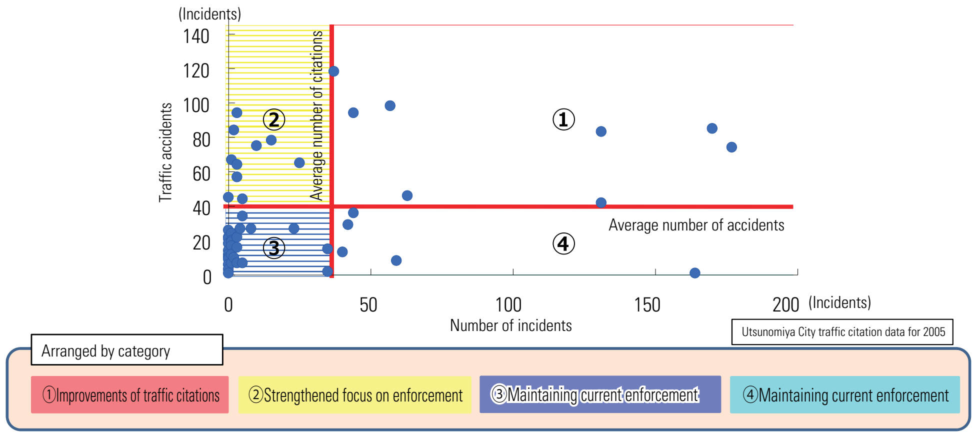


Figure 4. Example measures based on number of traffic accidents and number of incidents

3. Conclusions

This project performed a scientific investigation of the relation between traffic enforcement and traffic accidents on the basis of a summary of statistical data from the results of previous research. The results indicate that the relation between traffic accidents and traffic enforcement is strongly associated with regional characteristics, and that investigations should be performed on a regional basis.

The following is a summary of our major findings.

- Traffic enforcement has the effect of decrease the occurrence of frequent traffic accidents.
- First parties in traffic accidents are typically poor drivers with a history of repeated traffic violations.
- Repeated violations tend to be most common for drivers aged 25–34 years and to decrease beyond that age range.
- Traffic enforcement varies according to the conditions of individual cities and prefectures, and policies best suited to each locale are required.

4. Future outlook

Connecting the results of this research to a reduction in the number of accidents in actual society will fundamentally require consideration of measures on a regional basis. In 2013, we published *Kotsu torishimari handobukku* (the Handbook for Traffic Enforcement) to promote traffic enforcement that is effective for suppressing accidents. We hope this work will lead to efforts in accordance with the actual regional situation surrounding traffic accidents.

Interdisciplinary research on the criminal charge of dangerous driving causing death or serious injury

1. Background and goals

Dangerous driving causing death or serious injury is the formal crime for when drivers intentionally drive dangerously and the death or serious injury of another person or persons results. It is a natural reaction, from a certain point of view, to debate whether drivers should be charged with the same crime when tragic traffic accidents occur. Furthermore, in recent years, whether drivers can be charged with the crime when driving under the influence of alcohol, driving with diseases that potentially cause disturbances of consciousness, or driving without a driver's license has also become a major social problem when the death or serious injury of others results. A new bill is under preparation to include acts that have not previously been considered to constitute dangerous driving causing death or serious injury.

Such legislative response is certainly timely, but to properly proceed with the new bill without making penalties too strict, the law should be interpreted in line with the legal consciousness and the concept of justice among citizens. It is also necessary to scientifically investigate the adverse effects on driving of alcohol or drug use or diseases with potential disturbances of consciousness and publish the data to promote public awareness of dangerous driving.

2. Research content

Prior to the drafting of the above amendment, we conducted a study to deepen fundamental understanding of dangerous driving causing death or serious injury. Specifically, items related to the amendment were examined and analyzed. In addition, we studied case research conducted overseas to develop measures against habitual offenders. Here, we introduce some of our research findings.

2-1. Inspection of the amendment to include no entry roads and other types of roads

There is currently a movement to include "driving backwards on one way streets" in the amendment bill, due to extremely hazard posed. We think this is reasonable and is worth our support.

A similarly dangerous moving violation is to overtake and pass vehicle by traversing to the right across a no-passing center line. However, because many drivers must inevitably pass to the right to avoid illegally parked vehicles, it may be unwarranted to punish this act with no regard for the circumstances. Therefore, it was practical that this act was not included in the amendment as a punishable offence.

Entering residential roads closed to non-residents or entering time-dependent no-entry roads is

Project Leader: Takeyoshi Imai
Professor, Hosei University Law School

considered as dangerous as driving backwards on one-way streets, but this can happen accidentally and inadvertently. Therefore, drivers committing this type of violation should be punished after careful consideration of whether the drivers knew the corresponding traffic rules and regulations (negligent or intentional) before the act was committed.

2-2. Inspection of driving without a license by type (including the case of driving without an international driving permit)

The amendment is also considering a heavier punishment for drivers who cause moving violations equivalent to dangerous driving causing death or serious injury while driving without a license. We can support this directionality because the act of causing moving violations must be regarded as equally illegal to dangerous driving causing death or serious injury, and thereby the responsibility of the drivers considered comparably heavy.

Of course, because each case is different, drivers driving without a license need to be handled carefully after fine-grained investigation of their individual circumstances. For example, some drivers may not have a valid international driving permit in Japan because of failure to convert their license from overseas. When dangerous driving causing death or serious injury is committed by these drivers, their criminal intent to drive without a license may be denied for the exceptional reason of driving without knowledge of Japanese Law (no possibility of intentional violation).

2-3. Measures against drivers operating vehicles while intoxicated: Korea

An example of overseas measures against drivers driving while impaired (DWI) is shown below.

- DWI drivers are charged with dangerous driving causing death or serious injury if their blood alcohol content exceeds 0.1%.
- When suspended, DWI drivers are generally required to take traffic safety classes.
- DWI drivers may be sentenced to community service (40–200 hours).
- If a violator receives a DWI after having received two previous DWIs, their drivers' license will be revoked even if the moving violation itself would amount for license suspension under ordinary circumstances.
- Although it was possible for authorities to confiscate vehicles from habitual DWI offenders in the past, vehicle confiscation tends to be less frequent in recent years because confiscating vehicles and sentencing offenders to a fine is considered to be a double punishment, which may violate the Constitution.

2-4. Measures to promote social rehabilitation of drivers operating vehicles while impaired: the United States

Another example of measures against DWI is the driving while impaired court (DWI court) in the United States specifically for handling DWI offenders. The establishment of these courts started around 2003 because of the special measures required to handle DWI offenders who engaged in repeated dangerous driving due to alcohol dependency.

To understand the current situation surrounding DWI courts, we investigated the DWI court in Charlotte, North Carolina. The major findings are as follows:

- The DWI court handles only drivers who have been found guilty and are hardcore DWI offenders. (1)
- The DWI court forms teams of professionals to convict each driver with a comprehensive and proper sentence.
- Although physicians are not actual members of the team, they provide appropriate external medical opinions and recommendations.
- Under the direction of probation officers on the team, drivers convicted of DWIs are randomly subject to alcohol and drug testing 3–4 times a week. In addition, probation officers randomly inspect the drivers' home for alcohol or drugs.
- DWI drivers may be ordered to wear a secure continuous remote alcohol monitor (SCRAM, Fig. 1) on their ankle. This device scans the driver's skin to monitor and record the presence of alcohol.
- In recent years, the use of ignition interlock devices (IIDs, Fig. 2) is increasing. When DWI drivers start a vehicle equipped with an IID while intoxicated, their probation officer will be immediately informed.
- In addition, DWI drivers are ordered to use a breathalyzer at home or to install an IID in their vehicle. IIDs prevent an equipped vehicle from being started when the device detects alcohol in the breath of the driver.

Figure 1. Secure continuous remote alcohol monitor
(Source: http://blog.aacriminallaw.com/dwi/scram-bracelet-works/)

The recidivism rate of drivers who graduate from DWI court is considerably low compared with drivers who are sent to prison immediately after the sentencing. Another example is the program offered at the DWI court in the State of Georgia, in which 79% (an extremely high rate) of program attendants finish. The recidivism rate of drivers who attend the program offered by the DWI court (regardless of completion) is 15%, while the rate is 35% for drivers who do not attend.

Figure 2. Ignition interlock device
(Source: http://www.lifesafernca.com/interlock-video-en/)

(1) Hardcore DWI offenders: Drivers operating a vehicle with a blood alcohol content of 0.15 or above, or drivers operating a vehicle under the influence of alcohol after having been convicted of a DWI.

3. Conclusions

The intent of the above amendment as a measure against dangerous driving causing death or serious injury is tenable, and this review investigated the actual factors (mechanisms underlying dangerous driving and the cultivation of public awareness on prevention of dangerous driving) that could serve as the foundation of the bill. In this study, we also investigated advanced measures used overseas to respond to dangerous driving, such as DWI courts and IIDs. These measures merit attention in terms of proper punishment of and social rehabilitation for drivers who are convicted of dangerous driving causing death or serious injury.

4. Future outlook

To effectively utilize the present findings to reduce traffic accidents in the real world, it is essential to design and develop feasible measures. We plan to investigate multidirectionally whether a similar interlocking device or DWI court program may be applicable in the context of the Japanese legal system.

Smoothly promoting urban development for transportation through collaboration between government and local organizations

1. Background and goals

For promoting urban development for transportation, there are a growing number of cases where local organizations are created and these organizations work in cooperation with the government. However, rules have not been established regarding appropriate roles for each side, leading not only to insufficient communication but also situations where the two parties fall into rivalry.

This project aims at deepening the discussion of considerations and methodologies for promoting efficient and constructive cooperation between local organizations and government in specific areas, and thereby to obtain useful general knowledge.

2. Research content

2-1. Efforts toward consensus building in the Yanaka district

The Yanaka district in Taito ward, Tokyo, has a population of approximately 10,000 people. The district is notable for containing many temples and wood houses from the Edo period and earlier. The district faces traffic problems such as narrow streets that have become shortcuts for cars traveling at excessively high speeds, as well as disaster prevention problems caused by stretches of wooden housing along narrow streets, resulting in the district being classified as a potentially dangerous area in terms of disaster prevention.

Figure 1. Motor vehicles using residential roads as a shortcut

The most pressing traffic problem is the use of the narrow residential roads of the district as shortcuts for motor vehicles. This both increases danger to pedestrians and creates traffic-related problems such as noise and vibration in houses along these roads. Time-based restrictions on automobile egress have been established for roads frequently used as shortcuts, but such regulations are often ignored. There have been other attempts at improving the situation, but through traffic is a problem affecting a wide area, and so far no definitive solution has been found.

Project Leader: Hisashi Kubota
Professor, Civil and Environmental Engineering, Graduate School of Science and Engineering, Saitama University

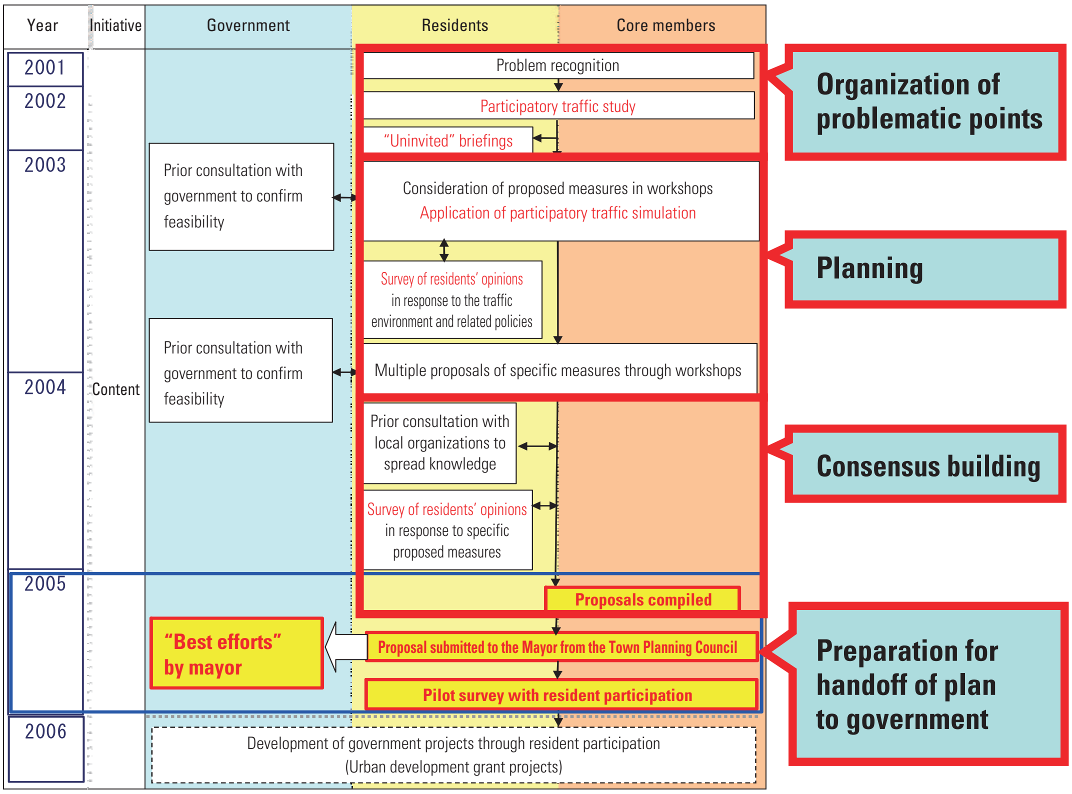


Figure 2. The consensus-building process of urban planning for transportation in the Yanaka district

The construction of large-scale apartments in the area has provided an opportunity for attempting to solve these problems. Toward that end, the Yanaka Town Planning Council was formed with the goal of constructing a cooperative framework between government and residents.

(1) Proposed plan

To investigate each theme concretely in urban planning, in the summer of 2003 the Yanaka Town Planning Council established three groups: the Disaster Prevention Subcommittee, the Environment Subcommittee, and the Traffic Subcommittee. The Traffic Subcommittee was formed with the goal of investigating strategies for dealing with important traffic problems in consideration of the overall urban development plan for the Yanaka district. The Traffic Subcommittee created a Yanaka district urban planning workshop as a way of involving all district residents in considering methods for improving local traffic problems.

The workshop was held 19 times between September 2003 and February 2006, providing a forum for participants to learn about traffic problems and to discuss potential solutions. At the 14th and 15th workshops, held in 2005, the results were presented of a survey that will be described below. Proposals for solutions to local traffic problems were summarized into a document, and based on the results of the workshops and surveys, the residents of the Yanaka district requested cooperation from the mayor of Taito ward in improving the traffic problems.

(2) Consensus building

For the purpose of consensus building between the government and residents regarding solutions to the traffic problems, two questionnaire surveys were performed in 2004 and 2005. All residents of junior high school age and older in the Yanaka district were included. A follow-up questionnaire survey was also conducted, targeting a sampling of households that did not respond to the initial survey. The questionnaire investigated awareness of traffic problems among residents in the Yanaka district.

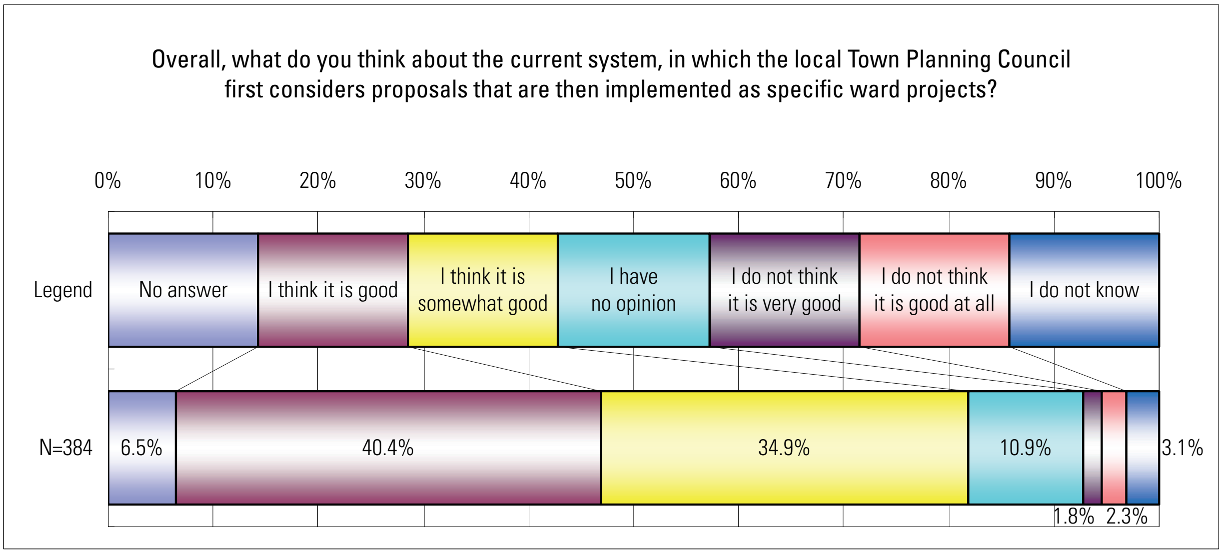


Figure 3. Resident survey results

(3) Handoff to government

The workshops and resident questionnaires resulted in two proposals for methods to take the first step toward improving traffic: installing physical devices on roads to lower vehicle speeds, and finding ways to improve enforcement of current traffic restrictions.

From this, a pilot survey with resident participation was performed, in which speed humps were installed along two residential roads in the district between February 17 and March 3, 2007. Speed humps are humps intentionally installed on roads to lower automobile speeds.

Figure 4. An experimentally installed rubber speed hump. Such experiments allow area residents to experience and evaluate impacts and effects. Noise and vibration is suppressed by the speed hump's sinusoidal shape.

At the same time, handmade mobile bollards (barricades such as those used during road construction) were installed to prevent the entrance of automobiles into residential streets. The handmade bollards were installed between February 20 and 23, 2007, and the mobile bollards were installed between February 20 and 22.

Resident questionnaires indicated a 70% approval rate for speed hump installation. Only 30% of residents responded “I think it is good” or “I think it is somewhat good” regarding the bollards, but this does not necessarily indicate dissent; most responses were “no response,” “no opinion,” or “I don’t know.”

Figure 5. A traffic bollard produced based on ideas from children

3. Conclusions

Obtained knowledge includes the importance of specific acknowledgment by residents themselves regarding place-setting for discussions, information sharing, barrier-free participation, and resident organization activities; the desirability of government and resident organizations coexisting for as long as possible for a smooth handoff to government; and the fact that organizations for discussion do not function as organizations for building consensus.

4. Future outlook

The implemented residential street safety features have spread nationwide; one example is the “Zone 30” initiative, which establishes zones within which the speed limit for all roads is 30 km/h or less. New devices are also being tested including “rising bollards,” which were installed in 2013 as a social experiment in Niigata City and also considered in the Yanaka district. Residential streets are an important target for further promotion of traffic safety in Japan, and as such require further safety measures and research.

Realization of earthquake disaster crisis management and a society with safe and secure transportation

1. Background and goals

The Great East Japan Earthquake was an unprecedented disaster that shook the foundation of Japanese society, which was previously expected to be safe and secure. IATSS was formed with the goal of contributing to the realization of a society with ideal transportation, and in the many years since its establishment, has performed interdisciplinary and international research studies toward that end. In the face of the disaster, however, the question has arisen as to how the association can contribute to the reconstruction of the affected areas and the creation of new regional communities.

As a result of discussion, IATSS recognized that it was particularly important for a society to have the three qualities: compactness/connectedness, redundancy and resilience. Taking these as keywords, we have collected proposals from five viewpoints: construction of resilient regional communities, promoting information management and awareness, the creation of new local industries, transportation systems with coexistence functions, and the legislation of liability rules and laws.

We hope that these proposals will contribute to the future recovery and reconstruction in disaster-affected areas, and that widespread development of the introduced measures will contribute to creating a society with safer and more secure transportation. Below we introduce several examples of the proposals described above.

2. Research content

2-1. Constructing a resilient society through smart choices

(1) Network-type compact cities

A network-type compact city is one in which the various attractive features of the city are consolidated (compacted) into multiple hubs, which are connected (networked) by various modes of transportation. Such a city has various functional units such as commercial centers, manufacturing centers, and tourism sites, which are intensively developed within a certain range and connected by various modes of transportation such as walking, bicycling, public transportation, and automobiles.

Compactness does not simply refer to the overall city as being in one place, but rather indicates the efficient aggregation of various attractive city features within suitable locations. It refers to aggregating

Project Leader: Kazuhiko Takeuchi
Director and Professor, Integrated Research System for Sustainability Science (IR3S), Todai Institutes for Advanced Study (TODIAS), The University of Tokyo

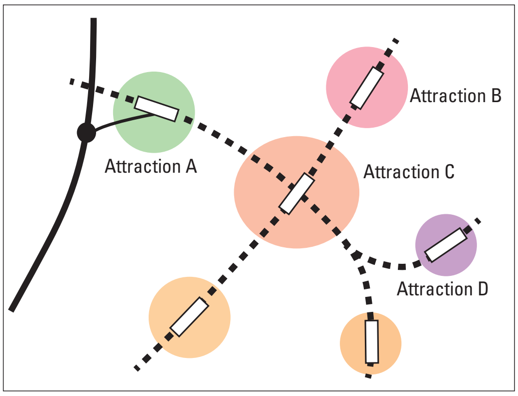


Figure 1. Network-type compact city

limited resources to enhance the attractiveness of sites, and interconnecting these attractive sites via various modes of transportation. Compactly connecting such aggregated sites (giving them compactness/connectedness) leads to ensuring mutual complementarity (redundancy) even if part of the city is affected by disaster, and flexibly performing recovery activities in other areas increases the resilience of the city as a whole.

City compactness is generally a result of repeated relocation of individual sites, and requires many years. In disaster reconstruction, on the other hand, there is a possibility of rapid recovery and consolidation. Rebuilding a disaster-affected city a model city for local governments throughout the country can provide an inspiration for overcoming the damage and tragedy of natural disasters.

(2) Multilayered transportation networks

Reconstruction following an earthquake disaster presents the opportunity for reconstructing the hierarchy of transportation systems in heavily damaged cities. High-speed traffic channels in particular should be preferentially secured to allow transport and delivery of both goods in normal situations and disaster-related goods in emergencies. Another necessity is the development of public transportation networks to better accommodate a super-aging society. The key to sustainable use of public transportation will be the development of transportation systems that can be stably utilized, as well as high-intensity utilization of the land surrounding train stations and bus stops.

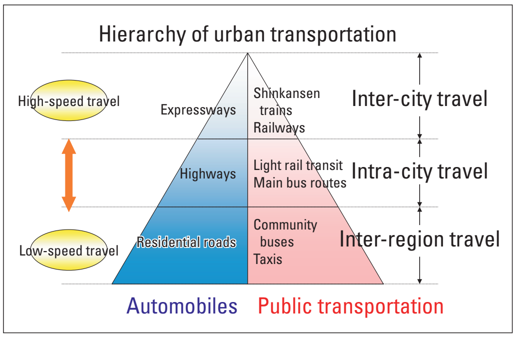


Figure 2. Image of hierarchy of urban transportation

In this way, appropriate division of roles between automobile and public transportation can ensure redundancy of transportation functions. Establishing sufficiently wide evacuation routes will allow smooth evacuations from low-lying areas to high ground, further improving post-disaster resilience.

From a variety of viewpoints, such as supporting disaster victims' ability to travel to school and work, and allowing transport of recovery-related goods, there is also a need for improving transportation networks between adjacent cities. Interconnecting cities over ranges sufficiently wide to include disaster-affected areas will improve redundancy of the region as a whole, as well as its resilience to natural disasters.

2-2. Creating a new commons for supporting local industry

Key industries in disaster-affected areas include agriculture, forestry and fisheries. In the case of the

Great East Japan Earthquake, these industries in particular were severely affected by the tsunami and nuclear power plant accident. Even before the earthquake, the affected area was experiencing stagnation of these industries due to reduced population and an aging labor force. What is needed in this area is a new business model for redevelopment, one that takes advantage of the fine mosaic structure of land and water usage that is characteristic of Japan.

Developing such a business model and tying it to regional redevelopment will require developing new systems for cooperative resource management involving companies, nonprofit organizations, and city residents. We propose such a model, which we call the "new commons." Unlike the traditional concept of a commons—a place maintained for the common good—it is necessary to foster the concept of a commons that allows participation by a variety of stakeholders.

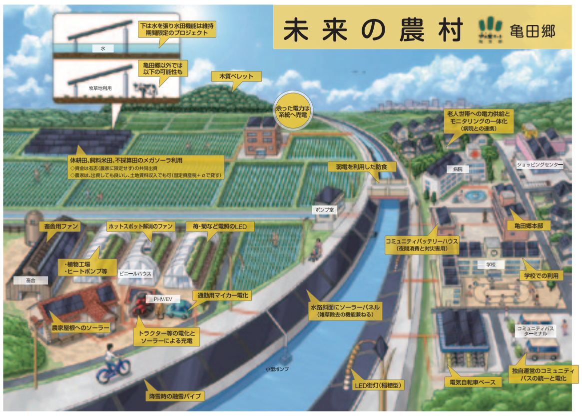


Figure 3. Image of rural area of the future
Source: Energy Sustainability Forum
(The University of Tokyo IR3S, Showa Shell Sekiyu K.K.)

Along with redevelopment of agriculture, forestry and fisheries as economically advantageous, high value-added industries, the promotion of eco-tourism and environmental education will be needed to gain outlooks on regional revitalization. There are increased expectations being placed on renewable energy such as solar, wind, and biomass as a consequence of the nuclear power plant accident, but the creation of new regional industries through introduction of concepts such as co-harvesting (reconciling renewable energy production with biological production) will likely be vital toward realizing renewable energy in rural areas. This will require introducing systems for co-management of natural resources into regional communities with consideration of regional circumstances, and building sustainable societies that are in harmony with nature.

2-3. Construction of a transportation system for coexistence of functions between ordinary and emergency times (Evaluation of quality of life as evacuees with consideration of traffic quality)

We propose a method for evaluating whether evacuees living in shelters or temporary housing during reconstruction maintain a certain quality of life (QOL), incorporating into the appraisal consideration of quality-of-trip (QOT).

Traditional traffic evaluations consider quantitative values such as degree of congestion, length of traffic jams, and point-to-point travel times. We believe the problem of system evaluations of transport quality is better addressed through appraisal of QOT. Even when living in emergency shelters, there are daily errands that people must attend to. The ease with which individuals can move to such destinations should therefore be considered an important evaluation criterion. When individually considering movement objectives such as commuting to work or school, shopping, or personal errands, in addition to distance traveled and ease of selecting methods of transportation, it is also important to consider factors such as the steepness of hills and anxiety during night-time travel. There are also other important evaluation metrics that should be finely tuned for individual areas, such as accessibility to friends and family, and accessibility to a community's important cultural sites on special days for public rituals.

The quality of transportation is an important part of quality of life. A proper understanding of this is a necessary part of efforts toward improving quality of life.

3. Conclusions and future outlook

Problems related to transportation have been a central theme in earthquake disaster reconstruction. However, we have attempted to go beyond this, considering a more comprehensive understanding of recovery and reconstruction that presents proposals and cases from a multifaceted point of view.

This paper introduced several examples of proposals from viewpoints based on three keywords, namely, "compactness/connectedness," "redundancy," and "resilience." All of the proposals are collected in "Aiming toward recovery and reconstruction of resilient regional communities: Five proposals and fifteen cases." We hope any interested readers will refer to this collection of proposals.

At the IATSS we have provided these proposals to the world through making recommendations to related local governments, academia, and international symposiums. We hope that such attempts have contributed to further IATSS-related earthquake disaster recovery efforts and to international society. These are important endeavors, and we look forward to further developments through IATSS projects.